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THEATER BATTLE MODEL (TBM-68). VOLUME VII.

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RESEARCH
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Volume VII
Technical Report

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RESEARCH ANALYSIS CORPORATION

McLEAN, VIRGINIA

FOREWORD

GENERAL

This document summarizes the work activities, discusses certain collateral investigations, and presents recommendations for future extensions of the project conducted by the Research Analysis Corporation (RAC) under the generic title, Theater Battle Model (TBM-68), for the National Military Command System Support Center (NMCSSC) of the Defense Communications Agency (DCA) to support a requirement of Limited War Division, Joint War Games Agency (JWGA), Organization of the Joint Chiefs of Staff (OJCS).

The task given RAC was to revise, redesign, and update an earlier JWGA war gaming manual, TBM-63, with the objective of providing the JWGA, US Unified and Specified Commands, and allied commands with a "valid and economic" means of evaluating planned operations. In mid-1966 representatives of the JWGA and DCA selected RAC as qualified for the task by virtue of 10 to 12 years experience in joint war gaming at every conflict level.

TBM-68 is comprised of five major models reported on in seven volumes: Volume I, Theater War Game Model (TWGM); Volume II, Theater Quick Game Model (TQGM); Volume III, Division Operations Model (DOM); Volume IV, Counterguerrilla Warfare Model (CGWM); Volume V, Amphibious Warfare Model (AWM); Volume VI, a COFRAM Supplement; and Volume VII, (this volume), Technical Report. These models permit war gaming across the spectrum of combat intensities and at various levels of aggregation.

CONSTRAINTS

Three major and frequently conflicting constraints imposed by the JWGA had to be constantly kept in mind as these models were developed and tested. First, they had to be comprehensive enough to reflect adequately and accurately the contribution of all services to the land battle. Second, at the same time, the level of detail had to be kept relatively low so that the respective games could be played manually—with no assist from computers. Third, the comprehensiveness was also to be accomplished within certain stringent user resource constraints, i.e., manpower and time-of-play required. Users of these manuals should keep these constraints in mind in evaluating the usefulness of the methodology.

THE USES AND LIMITS OF INDEXES OF FIRE POWER POTENTIAL (IFP)

The critical element in the assessment of ground combat interactions in the TBM-68 and most war games is the value used to indicate the relative military worth of a weapon or weapon system. In the TBM-68, this value is called the Index of Fire Power Potential (IFP). It is essential for users of these manuals to understand fully both the strengths and weaknesses of the IFP in assessment of ground combat interactions in these and most war games. Virtually all major manual or semi-automated war gaming models known to the authors employ a technique, varying in detail but not in principle, of estimating the relative combat potential of units in terms of estimates of raw firepower potential. These calculations for each combat unit, when normalized to the value ascribed to some base unit, are commonly described as Indexes of Fire Power Potential. A comparison of IFPs of opposed units defines the "force ratio" in the immediate conflict situation.

The criticisms of this purely physical measure of combat power are longstanding and well known, and need not be developed in detail here. Briefly, the principal short-comings are alleged to be that all other factors judged to be influential in combat, for example, mobility, morale, leadership, motivation, and logistics are apparently precluded from exerting influence on the combat operations. That this is not completely true will be pointed out below, but the important point is that the criticisms persist and need to be dealt with by those who presume to use the IFP concept in war games.

The expedient reason for continuing to use the measure of raw firepower potential is that, despite years of research, no better single-valued quantitative measures of combat potential have been delineated. But there are more positive arguments supporting the use of firepower potential which suggest that its validity may be greater than critics are willing to acknowledge. Although it may sound glib and superficial to say so, the fundamental role of combat troops in the Army's own words, is to "shoot, move, and communicate." The moving and communicating are means of enhancing the shooting or firepower potential. Ground combat, in effect, is an attrition process in which the victor combines firepower with maneuver and control to achieve the decisively higher attrition. Hence, all that is claimed for the IFP is that the ratios of such firepower potentials must tend to play a decisive role in the outcome of combat operations in the large. The whole thrust of weapons technology is, after all, to bring more firepower-per-combatant to bear on the enemy.

This does not mean that inevitably the force with the significantly higher IFP will, in the real world, always defeat its opponent. Nor does it mean that in war games an initially favorable force ratio deterministically prescribes the ultimate outcome of the conflict. What the force ratio does mean is that on the average the balanced force (of WWII and Korean type) with an appreciable firepower advantage should achieve

"success" as a result of greater attrition of the enemy than the friendly force receives. "Special-case" historical contradictions to this generalization are numerous, but there is no gainsaying that the side that shoots more—and moves effectively to enable it to shoot more—will be the winner, more often than not. Thus, the firepower balance is probably as good a measure as can be attained in war games and simulations for determining who "wins" on the average, given balanced forces in conflict over more-or-less extended periods. The IFPs used in TBM-68 are based on WWII and Korean experiences, where battle success was correlated with calculated force ratios in retrospect. Therefore, these IFPs presumably incorporate not only the element of superior firepower but also the effects of the tactical ingenuity and intensity with which firepower was applied, thus embracing implicitly the contributions of other non-quantifiable factors.

Furthermore, it should be emphasized that tabular representations of IFPs of units involved in a particular war game scenario are only initial inputs to get the game started. War game rules and assessment techniques provide means of adjusting the IFPs dynamically as a function of logistics capability or degradation, force posture, terrain, relative casualties, combat support reinforcement, maneuver, and surprise. Thus, as the battle progresses, the recalculations of force ratios do reflect, to an extent, the greater skill or endurance of one side over the other and the advantages or disadvantages imposed by terrain and prior preparation of positions.

Certainly it is not a requirement of TBM-68 for the gamers to accept the published IFPs as rigidly applicable to all situations they might encounter. For reasons stated below, the authors of these documents have selected a single set of such values, based on long-term averages in a particular combat situation, as applicable to the games played on the basis of TBM-68. However, users can alter these values as they see fit to accommodate special situations. For example, the ammunition expenditure rate, a major factor in the IFP calculation, could be assumed to be higher by some fraction in the early, intense stages of an assault operation. There may of course be an offsetting symmetry of friendly/enemy rates of fire, so that such a refinement may be redundant, but the determination of symmetry or asymmetry in such situations is a player or controller judgment.

The details of how player-controller groups can make these adjustments is spelled out in appropriate places in the text of each volume.

Two other legitimate concerns expressed frequently by users of IFPs should be mentioned in this brief comment.

First, it is frequently argued that seldom are all the TOE weapons of any unit at any echelon fired in the same combat operation and that therefore a TOE weapon count overstates the real potential. This comment overlooks the way the firepower potential is calculated: The important elements are

the kinds of weapons (and associated ammunition) present and the estimated daily unit expenditure of types of ammunition by type of combat, as specified in supply bulletins. Thus the ammunition expenditure is calculated as a constant, irrespective of whether all or only a fraction of the weapons delivered the ammunition.

Second, a more serious concern is whether the IFPs based on a firepower potential measure, which is a kind of rough translation of relative weapon lethalities, can be validly applied to units other than those of a size sufficient to have the combined arms present. The concern of course derives from the trend toward independent small unit (company) operations characteristic of the Vietnam war. It is true that use of small unit IFP should be accompanied by greater caution and more liberal exercise of judgment, but it still remains true that the number of weapons and the rate of ammunition expenditure on both sides must be the first and among the most important considerations in assessing the outcome of even small unit operations. The force ratio is, once again, a relative rather than an absolute measure.

Finally, as noted above, there is need to explain the reasons for selection for TBM-68 of a set of IFPs based on a long-term average value in a specific combat situation. The most important reason is that our experience suggests that, while the apparent reality of a gaming model is enhanced by detailed refinements of the numbers as combat conditions and postures change, it is not at all clear that the validity of the outcome is similarly enhanced. The calculated force ratio is a relative measure and is significant as a determinant of alternative battle outcomes only in fairly widely spaced increments, such as force ratios 1:1, 1.5:1, 2.0:1, and 2.5:1. Small changes in IFP values in different situations do not appear too important in changing the battle outcomes based on such spaced values largely because we can expect enough offsetting symmetry in two-sided games to override small variations in the ratio. It would be helpful to be certain that marginal variations in the force ratio attributable to changes in IFP values in the different phases of operations could become the basis of choices among alternative force capabilities, but it is felt that the measuring tool, at present, is too crude to provide this reassurance.

A lesser reason for our choice is that it is felt that we could not—under the constraints of time and costs—both for RAC in developing TBM-68, and for the future game players using it—introduce an elaborate system of IFPs that would have to be frequently recalculated by terrain class, by assessment interval, by phase of operations, and by posture. Actually, we have made some tentative moves in this direction by permitting players to vary the rate of fire, within limits, in both the AWM and the DOM. Even so, care must be exercised in making such adjustments since there is questionable advantage to increasing the degree of detail beyond the level which can have an influence on the aggregated assessments.

The foregoing caveats about the meaning and uses of IFPs were felt to be of sufficient importance by RAC, JWGA, and the NMCSSC to require emphasis by inclusion in the Foreword.

ACKNOWLEDGEMENTS

Most of the work on this project was done by members of the Military Gaming Department at RAC but valuable contributions were also made by analysts from three other departments; Logistics, Combat Analysis, and Science and Engineering. The authors of this volume were Richard E. Zimmerman, Charles A. Bruce, Jr., Herbert J. Vander Heide, Maj Gen USA (Ret), and Norman W. Parsons, Lt Col USA (Ret).

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Chapter 1

CONTRACT DESCRIPTION

1.1 CONTRACT

On 1 November 1965, the Joint War Games Agency (JWGA) announced a program to revise the Theater Battle Model (TBM-63) and requested comments from the Services, and the unified and specified commands. On 26 January 1966, the JWGA placed the requirement for revision of TBM-63 with the Defense Communications Agency (DCA/NMCSSC). On 23 February 1966, DCA/NMCSSC solicited comments on the availability of Department of the Army (DA) and the Research Analysis Corporation (RAC) for this project. On 23 March 1966, DA stated support of the proposed revision and made RAC available for the project. On 22 July 1966, MIPR 42-6-43 was issued by DCA to DA in the amount of $837,200 for payment to RAC for 22 Technical Man Years (TMY) of effort for this project. The US Army Research Office (DA/OCRD), as the contracting office, accepted the MIPR on 2 August 1966, and Task Order 6 to Contract No. DA 44-188-ARO-1 was assigned. The starting date by RAC was 1 August 1966, and the completion date was scheduled to be 31 January 1968 for the model and 15 March 1968 for the final technical report.

The project's general objective was to redesign, refine, and update the Theater Battle Model (TBM-63) with emphasis on quality improvements in order to make this manual, joint, limited war gaming model more flexible and universally acceptable to meet the varying war gaming requirements of the joint staff, the Joint War Games Agency, the unified and specified commands, and the Services. In addition, the manual model was to be designed so that a sanitized version may be provided to SHAPE and allied countries and so that elements of it can be computerized in the future.

The new model retained the title Theater Battle Model: short title, TBM-68. The contract was monitored by the Development Branch, War Games Analysis Division, NMCSSC on behalf of the JWGA.

1.2 WORK ACCOMPLISHMENTS

Appendix D is a summary of the work accomplished under this contract.

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Chapter 2

COMPUTERIZATION OF TBM-68

2.1 GENERAL

The Technical Work Statement for revision of Theater Battle Model (TBM-63) requires that RAC, as contractor for the TBM revision (TBM-68) include in its final technical report its recommendations on computerizing all or part of TBM-68. The desired scope and specificity of such recommendations were subsequently worked out by the JWGA/NMCSSC project officer and RAC. The major issues or questions to be addressed are as follows:

The general benefits and costs of computerization of ground combat war games. This discussion would consider separately the computerization of record keeping, game assessments, and player-decision functions. Benefits would be reflected in reduced manpower required to play the game or reduced real time to achieve a given length of simulated combat time or both. Costs would include, of course, the one-time investment of programming resources to achieve computerization, but might also be reflected in decreased "visibility" in the operations depicted by the computerized subroutines, with a consequent decrease in confidence in the models by the occasional military user.

The extent to which it might be desirable to computerize certain major models or submodels rather than all, in the light of the benefit and cost considerations above.

Estimates of the manpower costs to achieve recommended computerization tasks and estimates of the savings of time that might thereby accrue.

Discussion of the compatibility of certain existing or projected computer war games programmed or to be programmed for the RAC computer with other computers potentially available to users of TBM models.

This chapter attempts to address the foregoing issues and on the basis of these considerations makes recommendations for a course of action to JWGA/NMCSSC.

2.2 LEVELS OF COMPUTER ASSISTANCE

Several levels of computer assistance to war gamers are possible. These range from computer record keeping and analysis of the results, through programming some or most of the assessment routines, and finally, programming the entire operation, including the decision function of the players. This last constitutes what is commonly termed a "pure computer simulation," or "simulation" for short.

2.3 RECORDS

Now it is a truism that any procedure that is accurately and quantitatively described may be programmed for the computer. Three aspects of the war game process were mentioned above: records, assessments, and the player function. Thus the central question is the degree to which each of these functions has been "accurately and quantitatively" described. No great amount of time is required to consider the first of these— the records. By their very nature they are quantitative and the computer may profitably be programmed to process these records, that is, analyze them in the light of war-game objectives.

2.4 ASSESSMENT

The second procedure, assessment, is a considerably more difficult problem for computer coding. It is common in war games to proceed according to a considerable body of rules described in quantitative terms. Such rules may readily be programmed for the computer. In the TBM-68 family of games, most of the rules are of this nature. However, a significant number of assessments are based on the professional judgment of the controller. Thus to program the assessment function in its entirety would require that quantitative rules be developed to replace the professional judgment now required. But it is also feasible to program part of the assessment procedure for the computer while retaining acts of judgment to supplement the computer. The advantages of computerized assessment to increase accuracy and reduce tedious hand calculation are obvious. There are other significant qualifications, however. In the first place, use of the computer for assessment in order to speed up play requires that an acceptable computer turnaround time be feasible, lest the savings in assessment time be lost waiting to gain access to the computer. In terms of the designed pace of play of the TBM-68 family of games, turnaround time should probably be no more than 2 hours.

A second point of concern involves the compatibility of types of computer available to prospective users of computerized games. The contract developers of the necessary programs would, of course, base their programming efforts on hardware available to them. RAC's computer is the CDC 6400. It would obviously be highly desirable, if not essential, that RAC, if it were the developer, would use CDC 6400 software since otherwise the testing and debugging procedure would be clumsy and time consuming. A determination must therefore be made as to whether the developers' computer program would be compatible with computers that JWGA or other users might employ.

2.4.1 Judgment in TBM Assessments

Table 1 illustrates the magnitude of the problem of programming the assessment routines of the TBM family of war games. This table gives estimates of the percentage of the rules of each submodel which require the exercise of professional judgment. Thus if an effort were to be made to program the TBM family for computer assessment, time would have to be made available to establish what portion of the assessments based on judgment would have to be reduced to a rule and what portion could continue to be determined by judgment. There is no question about the feasibility of doing this. It has been done many times. But it is not a straightforward job and requires considerable design skill coupled with military judgment. It should be noted that, with computer assistance comes the possibility of adding considerable detail to the rules, with a probable increase in realism. In this connection it can be noted that RAC has three computer-assisted games which compare to three of the TBM family. These are: Tacspiel, which compares to the DOM; Theaterspiel, which compares to the TWGM; and the Computerized Quick Game, which compares to the TQGM. STAG has a similar family. Thus any effort to computerize the assessment of the TBM family has adequate precedent. RAC takes the position that doing so is both feasible and desirable.

Table 1

PERCENT OF ASSESSMENT BASED ON JUDGMENT

Model									
Theater War Game Model		Theater Quick Game Model		Division Operations Model		Counterguerrilla Warfare Model		Amphibious Warfare Model	
Submodel	%	Submodel	%	Submodel	%	Submodel	%	Submodel	%
Gnd combat and combat spt	10	Gnd combat	10	Cmd and comm	15	Cmd and comm	15	Intell	5
Air	5	Air	20	Mvmt and contact	50	Mvmt and contact	20	Fire spt	5
Intell	5	Logistics	--	Intell	10	Intell	--	Air	10
Logistics	5			Gnd combat and combat support	30	Gnd combat	10	Ship-to-Shore	20
Nuclear	10			Logistics	50	Logistics	--	Mine warfare	5
Chem-Bio	5			Engr spt	75	Engr spt	20	Small craft opn	10
				Air and air def	20	Air spt/air def	--	Nuclear	5
				Air mobility	15	Air mobility	10	Ship ident	5
				Nuclear spt	20				
				Chem-Bio	50				

2.4.2 Estimates of Computerization Costs in Manpower

JWGA/NMCSSC has indicated that the next step in the evolution of the TBM family will be to computerize appropriate parts of the assessments, leaving the player-decision function still operable. Initial estimates have been made by RAC concerning the magnitude of this task. These estimates were arrived at after consultation with members of the RAC Computer Sciences Center familiar with war game models, with the respective principal authors of the TBM family, and after an intensive 2-week study of programming requirements for the AWM—routine by routine. Estimates for the DOM were made by comparing its rules with the AWM. They also reflect RAC experience with prior programming tasks for its own family of computer-assisted games. Table 2 summarizes these estimates, with those other than AWM or DOM done by analogy. Once computerized the games are expected to be speeded up by a factor of between 2 and 3, depending on the turnaround time associated with the computer facility.

Table 2

ESTIMATES OF MANPOWER
FOR COMPUTERIZATION OF TBM-68

Model	TMM
TQGM	7
DOM	84
AWM	83.5
TWGM	200
CGWM	70-90

JWGA/NMCSSC has suggested that this work would probably be undertaken in phases. A logical procedure in RAC's view would be first to substitute ATLAS (RAC's Computerized Quick Game) for the TQGM; then computerize the DOM and AWM as a package. This leaves the massive TWGM and the CGWM for later phases.

2.4.3 Adapting ATLAS to the TQGM

RAC believes and recommends that no effort be spent in computerizing the TQGM. Rather ATLAS—on which the TQGM was patterned—and already part of the "public domain"—should be used in its place. This simulation has been used by and for a variety of Army, DOD, JCS, and command agencies for several years and has proved its usefulness.

It is a pure simulation; the player function is implemented by review of the progress of a complete theater campaign, then judging if and where some redeployment of troops should have been effected, after which the simulation can be rerun. Experience has shown that this is a very satisfactory mode of operation. However, completion and editorial treatment of the ATLAS documentation is required so that it can be used completely independently of RAC participation. Six TMM are allocated for this purpose, and RAC recommends this as first priority. ATLAS is presently programmed for the CDC 6400 and the CDC 3600. Conversion to another 3000 series computer should take no more than 1 TMM.

2.4.4 Computerizing the DOM

Since computerization of the DOM has been recommended as the logical task to be undertaken next, detailed estimates of the execution time and manpower have been made. Experience has shown that this work should be undertaken in four phases: (1) computerization; (2) test; (3) documentation; (4) editorial. One year should be allowed for the first two phases and 6 months each for phases 3 and 4, yielding a total of 2 years for the project. Table 3 summarizes these details.

Now certain of these subroutines can be considered as optional for computerization. Thus the highest priority might be given to a truncated program suitable for conventional warfare only. Deleting the Nuclear and Chem-Bio Submodels saves 8 TMM from computer programming, 3 TMM from Phase 3, and 1 TMM from Phase 4 for a total savings of 12 TMM. This would reduce the manpower required to 72 TMM or 6 TMY.

If a minimal program is required, consideration could be given to deleting Engineer Support, Air and Air Defense, and Logistics Subroutines, which reduces the total requirement to 67 TMM or about 5.5 TMY. RAC is unable to anticipate whether this approach would yield a useful program in terms of the particular needs of the JWGA and other users although RAC itself has frequently used such a "bare bones" program.

Table 3

ESTIMATES OF MANPOWER
FOR COMPUTERIZING THE DOM

		TMM
Supervision and Administration		12
Analyst		12
Phase 1: Computer Programming		
Submodel		
Status File	1	
Input/Output	1	
Command and Communication	2	
Movement and Contact	3	
Intelligence	3	
Ground Cbt and Cbt Spt	5	
Logistics	2	
Engineer Support	1	
Air and Air Defense	2	
Air Mobility	3	
Nuclear Support	4	
Chem-Bio	4	
Total		31
Phase 2: Test		5
Phase 3: Documentation		18
Phase 4: Editorial		6
Total		84 (7 TMY)

2.4.5 Computerizing the AWM

The detailed estimates of the manpower required to computerize the AWM are shown in Table 4. The same four phases are envisioned. Similarly, some truncation is possible, with certain subroutines such as, Intelligence, Nuclear, and perhaps Small Craft components being played manually or not used at all.

Table 4

ESTIMATES OF MANPOWER
FOR COMPUTERIZING THE AWM

		TMM
Supervision and Administration		12
Analyst		12
Phase 1: Computer Programming		
Input/Output	4.0	
Status File	2.0	
Submodel		
Intelligence	1.5	
Fire Support	3.0	
Air	6.0	
Ship-to-Shore	8.0	
Mine Warfare	1.5	
Small Craft	0.5	
Nuclear	1.5	
Ship Identification	1.5	
Total		29.5
Phase 2: Test		6
Phase 3: Documentation		18
Phase 4: Editorial		6
Total		83.5 (7 TMY)

2.4.6 Computerization of the TWGM

No detailed estimates of resources required to computerize this very large war game model have been made. However, by analogy a crude estimate of 200 TMM (16.7 TMY) seems reasonable. The bases for RAC's view that this task should be accorded lower priority are as follows. First, the "lessons learned" in first phase efforts and applications will indicate more definitely the desirability of computerizing all or part of this massive model. Second, to develop a TWGM program in parallel with the DOM-AWM package would severely tax (if not exceed) the programming resources of most contractors. And, third, it appears to RAC that since there already exists a fast, economical model (ATLAS) widely used in theater gaming where iteration is required, the use of TWGM will probably be reserved for those analytic tasks where time and resources are abundant and where detailed, methodical gaming is of more importance than rapid, aggregated iteration. In such situations manual play should suffice.

2.4.7 Computerization of CGWM

Computerization of the CGWM has been put off for a second or third increment, since the much more fluid and less well understood nature of the combat depicted raises methodological questions which can only be resolved with additional research. These state-of-the-art shortcomings may, in fact, make it desirable to continue to employ this model manually so that developments are clearly visible and subject to easy modification by players. Assuming that these difficulties may be surmounted, a rough estimate of the manpower required is in the neighborhood of 70-90 TMM.

2.5 COMPATIBILITY OF CDC COMPUTERS

It has already been noted that developing the computer program in a language compatible with the computer available to the contractor is desirable. In the case of RAC, this is the CDC 6400. It has been suggested that NMCSSC may get a CDC 3000 series computer. It is entirely possible to program on the CDC 6400 so that the war game may be run on either computer.*

One other point to be noted is that portions of the DOM have been programmed for the CDC 1700, which has a cathode ray tube (CRT) input/output device. It has been established that this program may not be readily adapted to the present application, since its calculations are heavily dependent on use of the CRT.

*RAC would prepare the programs using FORTRAN IV.

2.6 COMPUTERIZATION OF PLAYER FUNCTION

The third and highest level of computerization involves programming the player function. If this is successful the payoff is very great indeed. Rather than being restricted to a few or several war games to meet the needs of a study, dozens of computer simulations may be run off, thus establishing the sensitivity of the results to uncertain assumptions.

Several computer simulations of battle have been designed. For example, there is already in existence a computer simulation associated with the TQGM of the TBM family. It is the RAC Computerized Quick Game. In general, the state of the art of reducing to a computer routine the act, by a player, of making a tactical decision, is low. However, RAC feels the potential benefits of even a partial success are so great that work in this area is justified. Once the basic studies of the logical structure of tactical decision have been completed, it should be possible to transform each member of the TBM family into a pure computer simulation. Several years of intensive study will be necessary.

2.7 SUMMARY RECOMMENDATIONS

In the light of the foregoing, and in the light of RAC's present understanding of JWGA/NMCSSC desires to program TBM computerization in several phases, RAC recommends an initial phase of 18-24 months duration which would accomplish the following:

Document for independent use the RAC ATLAS Model as a preferred alternative model to a computer version of TQGM.

Computerize record keeping and assessment procedures of DOM, but if resources do not permit full computerization immediately, computerize initially the first five submodels indicated in Table 3.

Simultaneous computerization of the AWM to the extent that resources permit but at least through the first four submodels indicated in Table 4.

Chapter 3

ADDITIONAL INVESTIGATIONS

3.1 INFANTRY-TANK TRADE-OFF IN SMALL UNIT ENGAGEMENTS

3.1.1 Purpose

A research project based on a computer simulation was undertaken to explore the possibility of determining infantry-tank trade-off in ground combat of small unit engagements. When fully successful, this will permit developing much improved firepower scores for tanks. However, the work reported on here must be considerably extended before sufficiently general trade-offs can be obtained. A more detailed report is contained in App A.

3.1.2 Discussion and Scope

A Monte Carlo computer simulation, CARMONETTE, developed by RAC, served to produce outcomes of battles of various attacker and defender force mixes of infantry platoons and tanks. Of primary interest was the capability of the CARMONETTE simulation to produce replications of small unit engagements and, subsequently, the establishment of statistical analyses concerning the average results of various attacker force mixes with respect to a constant defender force mix. Specifically, from a series of CARMONETTE simulations of varying attacker mixes of infantry platoons and tanks against a constant defender force mix, certain constant-effectiveness attacker force mixes can be established. Thus the trade-off between attacker infantry and attacker tanks can be evaluated for the situations studied.

Although the greater part of the study produced plausible results, difficulty in the interpretation of one series of simulations was encountered. Considerable effort was expended to determine the statistical validity of the plausible results and on discounting the apparently irrational results.* Since this was only partially successful, and since only one tactical situation could be studied within the limits imposed on the study, the results were not introduced into the TBM firepower score system.

*Here and elsewhere "irrational" results are mentioned and were thought to be caused by statistical fluctuations. This speculation has been confirmed by later work available in unpublished notes at RAC.

3.1.3 Forces Simulated

The defender forces consisted of units representative of an armor-reinforced infantry rifle company with artillery support. The attacker force consisted of units representative of an armor-reinforced motorized rifle battalion combat team with artillery in direct support. The makeup of the defender units and their weapons, four mixes of infantry platoons and tanks (2-2, 1-3, 3-1, and 2-3, respectively), was in accord with the current ROAD TOE.

The attacker force was organized to match present estimates of Soviet mechanized forces but was equipped with US weapons. The combinations of mixes in the attacker forces were varied both in infantry and tank strength. The infantry platoon strength ranged from 2 platoons to 9 platoons. Commensurate infantry support fire was provided as infantry platoon strength varied. Armor varied from as few as no tanks to as many as 17 tanks in the attacker force mix. Details of the forces and their characteristics are reported in App A.

3.1.4 Technique of Analysis

From the simulations conducted for each defender force mix, an estimate was made of the number of attacker tanks required to produce a 0.5 probability of mission success, for each of the various infantry strengths for the attacker. Success for the attacker occurs when the defender suffers 50 percent casualties before the attacker force has suffered 40 percent casualties.

The win-loss outcomes of combinations of attacker force mixes were fitted to the dichotomous (two-valued) model

$$P_s = (1 + e^{-Z})^{-1}$$

where P_s = probability of success

"Z" is a function of attacker infantry and tank strength, and artillery rate of fire where necessary, and is defined as

$$Z = a_0 + a_1 I + a_2 T + a_3 IT + \ldots$$

where a_i = i^{th} coefficient
I = no. of attacker infantry platoons
T = no. of attacker tanks

The values of the coefficients are determined in a manner roughly similar to the well known least-squares curve fitting technique. The resulting P_s is the best estimate of the true probability of success associated with the game results.

3.1.5 Results

A total of 986 simulations comprised the data sample. The various combinations of infantry platoons and tanks of the attacker force mixes simulated are given in Table 5 for specific artillery rates of fire against the several defender force mixes employed.

Table 5

SIMULATIONS CONDUCTED

Defender		Arty rate of fire	Attacker force mix combinations	Simulations
Inf plats	Tanks	(rds/min)	investigated	conducted
2	2	1.67	41	150
2	2	1.11	45	177
2	2	0.83	11	29
2	2	None	5	5
1	3	1.11	34	199
3	1	1.11	25	138
2	3	1.11	39	276
2	3	None	2	12

Several different functions of Z were assumed and derived in evaluation of $P_s = (1+e^{-Z})^{-1}$. Positive results were obtained for two combinations of the defender force mixes investigated. Examples are shown in Figs. 1 and 2 for the 2 platoon-2 tank defender force mix and for the 1 platoon-3 tank defender force mix, respectively. In the case of the 3 platoon-1 tank defender force mix, the outcome of even the greater attacker strengths resulted in attacker wins with less than 50-percent probability of success. The simulations involving the 2 platoon-3 tank defender force mix resulted in irrational outcomes from statistical fluctuations and made results of model fitting incomprehensible.* (See para 4.5 in App A.) These results are discussed in full in App A.

*See footnote on page 14.

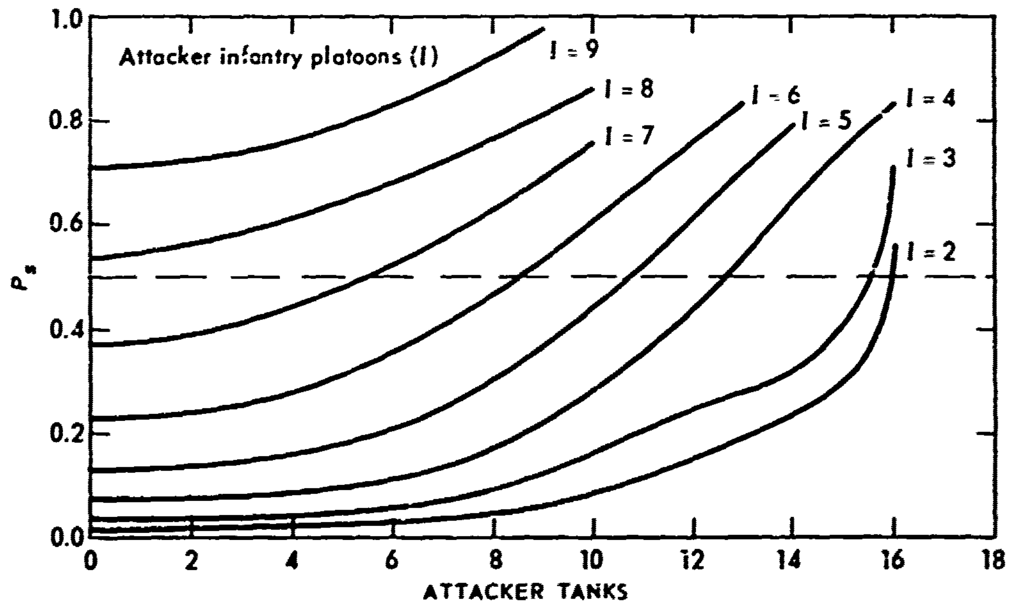

Fig. 1 —Probability of Success Curves, 2 Platoon–2 Tank Defender
Arty rate of fire ≅ 1.11 rds/min.

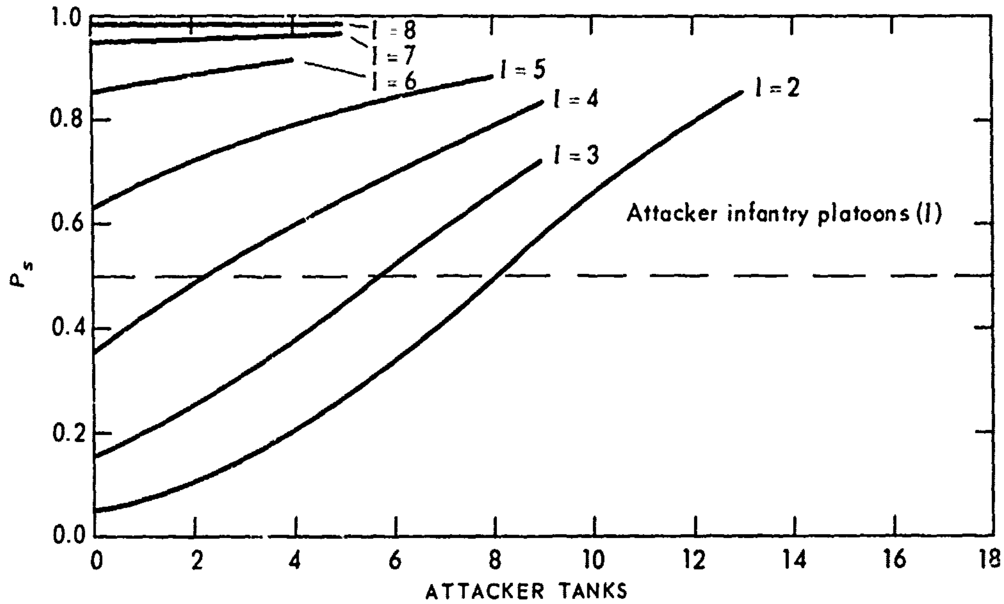

Fig. 2—Attacker Probability of Success Curves, 1 Platoon–3 Tank Defender

Arty rate of fire ≡ 1.11 rds/min.

From the families of attacker success curves for increasing tanks of the attacker. 50 percent success force mixes may be obtained. These plots of 50 percent mission success force mixes yield trade-off curves against the defender force mixes as shown in Fig. 3. As is apparent in Fig. 3, the trade-off curves are essentially linear, implying a uniform trade-off in attacker infantry and tanks. These curves permit calculation of the number of tanks equivalent to one infantry platoon in effectiveness as related to this particular tactical situation. These linear trade-offs are given in Table 6 for the 2 platoon-2 tank defender with several artillery rates of fire and for 1 platoon-3 tank defender force mix at one level of artillery rate of fire.

Table 6

ATTACKER TANK-INFANTRY PLATOON TRADE-OFFS

Defender force mix		Artillery rate of fire (rounds/minute)	Attacker tanks per Inf platoon
Inf plats	Tanks		
2	2	0.83	2.0
2	2	1.11	2.1
2	2	1.67	2.8
1	3	1.11	2.9

3.1.6 Validity of Results

As previously stated, the simulations involving the 2 platoon-3 tank defender force mix resulted in irrational outcomes. These results cast doubt on the validity of the total results of the study.* Several explanations have been advanced to explain these irrational results as due to statistical fluctuations. Several statistical techniques have been employed to explain the irrational results and validate the results which are plausible. Two such statistical techniques will be described.

The use of a widely known nonparametric statistic, chi-square, indicated statistically significant results when the test was employed to establish confidence as to goodness of fit of the plausible simulation outcomes. Little (or poor) statistical confidence was established for the irrational outcomes by the same test. See para 4.5 App A.

*See footnote on page 14.

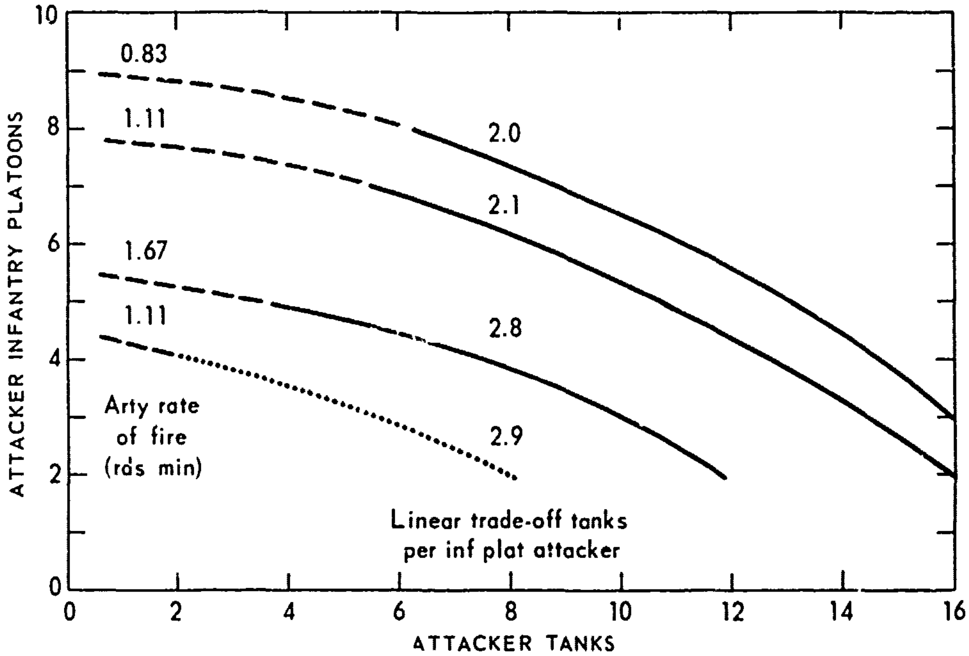

Fig. 3—Trade-Off Curves Resulting from CARMONETTE Simulations of 2 Platoons and 2 Tanks Defender and 1 Platoon–3 Tanks Defender

Defender Force-Mix: —— 2 platoons–2 tanks ·········· 1 platoon–3 tanks

Another statistical technique involved statistical confidence bounds from multiple regression analysis of a variable based on the simulation casualty criteria. Similar analysis was conducted on the irrational outcomes and on the results of one series of simulations which appeared reasonable. The confidence bounds further supported the validity of reasonable simulation outcomes (of simulations involving defender of one platoon and three tanks). Furthermore the confidence bounds of the irrational outcomes showed a large area of unexplained (experimental) error in the data.

3.1.7 Derived Firepower Score of Tanks

The firepower score for an attacker tank in terms of an attacker infantry platoon were derived from the previously established trade-offs of Table 5.

Firepower measures, as given in the TBM-68 documentation, were combined to calculate the scores of the attacker infantry platoons. The total of AP and AT IFPs were used. Several alternatives in regard to artillery effectiveness were considered in the computation of the average firepower score per infantry platoon. The alternatives were (1) a 5 percent degradation factor on artillery as infantry decreased per platoon; (2) a proportionate sharing of artillery as infantry decreased; (3) a constant firepower of artillery regardless of the change in infantry strength; and (4) an exclusion of the artillery firepower in computation of the infantry platoon score.

A synopsis of the derived firepower score of attacker tanks (as given in App A, Table A-17) are presented in Table 7 for two defender force mixes and for the rate of artillery fire of 1.11 rounds per minute.

The firepower score credited to an M-60 tank in the TBM-68 firepower listing (Table A-3, App A, Vols I-V) is 0.605.

Table 7

DERIVED FIREPOWER SCORE OF ATTACKER TANKS

Defender		Linear trade-off	Average firepower score for	Derived firepower score of
Inf platoons	Tanks	(tank/inf platoon)	Inf platoon	tank
With 5% degradation factor on artillery				
2	2	2.1	2.752	1.31
1	3	2.9	3.630	1.25
With proportionate share of artillery				
2	2	2.1	2.025	0.96
1	3	2.9	2.025	0.70
With constant firepower of artillery				
2	2	2.1	3.339	1.59
1	3	2.9	4.639	1.60
With exclusion of artillery firepower score				
2	2	2.1	0.720	0.34
1	3	2.9	0.720	0.25

3.2 HERO CASUALTY STUDY

The Historical Evaluation and Research Organization (HERO) under a subcontract with RAC, conducted a study of historical sources to determine the relationships between casualties, size of forces involved, and type of combat operations. An abstract of the HERO study is included as App B of this report.

3.2.1 Basis of Study

Data are presented for casualties to the attacker and the defender for 37 engagements which occurred during World War II and the Korean War. The availability of suitably detailed records for each of the opposing sides in the engagements limited the number of combat operations that could be considered and prevented consideration of units smaller than division size as had been planned originally. The limited number of engagements for which records were available also prevented consideration of terrain as a possible influencing factor on casualty rates.

Of the 37 engagements for which data are presented, 11 occurred in Europe and 15 on Okinawa during World War II, and 11 occurred during the Korean War. The US forces were the attacker in 29 of the engagements and were the winner in 24 of them. The US forces were the winner in all 8 of the engagements in which they were the defender.

3.2.2 Analysis of Data

The data in the HERO report identifies the posture of the defender as being one of five types: fortified defenses, prepared defenses, hasty defenses, delaying action, or withdrawal. Examination of the data showed that in the four cases of withdrawal the defender had also been assigned one of the other postures; the withdrawal posture was therefore dropped since the casualty data associated with this posture could not be separately identified.

To analyze the data for incorporation in the TBM-68 models, the engagements reported on were grouped according to the defender posture and according to the side judged the winner as follows:

Defender posture	No. of cases	Wins Atkr	Wins Dfdr
Fortified defenses	9	8	1
Prepared defenses	7	2	5
Hasty defenses	11	6	5
Delaying action	10	7	3

An attempt was made to plot a curve for each of the defender postures separately for attacker and defender wins. However, the spread among the individual data points and the small sample size shown in some of the cases made it impossible to separate the data in this manner. The data then was grouped into two sets of defender posture with fortified and prepared defenses in one set, and hasty defenses and delaying action in the other set.

The data points are plotted in Figs. 4 and 5 with smoothed curves of the values. A least-squares fit was also calculated, however, the resulting curves were not monotonic and were not used.

The force ratio used in the presentation of the data is the geometric mean of the manpower ratio and the firepower ratio of the forces in each engagement as reported by HERO. The range of the force-ratio figure is from a low of 0.35 to 1.00 to a high of 40.5 to 1.0.

The range of casualty rates is from a low of 0.12 percent to a high of 19.3 percent for attacker casualties and from a low of 0.24 percent to a high of 44.2 percent for defender casualties.

In the set of engagements considered there were no cases of the attacker losing when the force ratio was greater than 2.5 to 1.0 and no cases of the attacker winning when the force ratio was less than 1.16 to 1.0. Only in the force-ratio range of from 1.16 to 1.0 to 2.5 to 1.0 are there cases of both attacker and defender wins.

3.2.3 Results

The curves in Figs. 6 and 7 were then prepared for use in developing the casualty-assessment tables for the TBM-68 war game models. In these figures the solid line portions of the curves are derived from Figs. 4 and 5. The dashed line portions of the curves are extrapolations to provide a full set of casualty vs force ratio relationships for both attacker and defender wins.

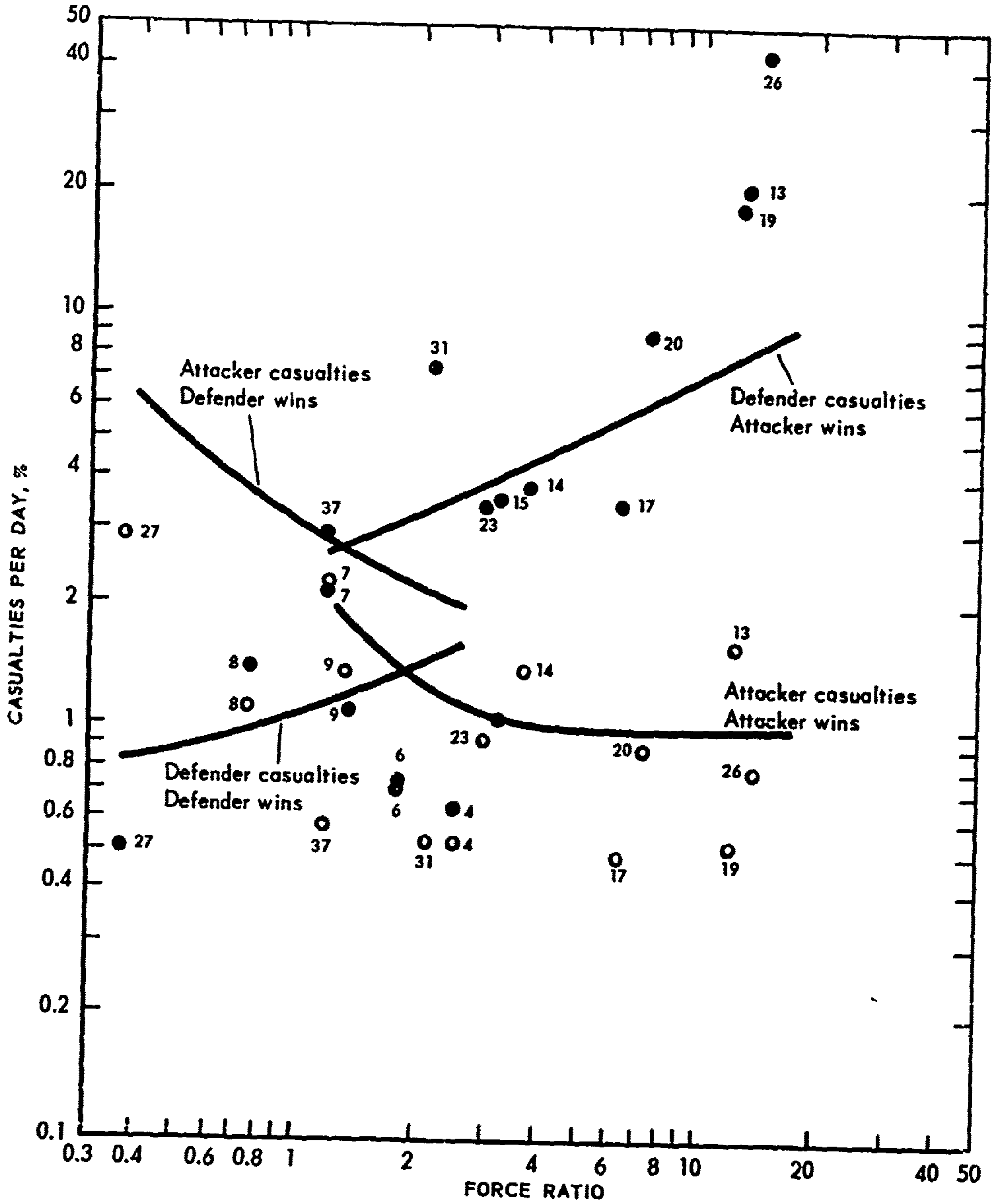

Fig. 4—Casualties vs. Force Ratio—Defender in Fortified or Prepared Positions

Numbers refer to engagements listed in Table B-2.

o —Attacker ● —Defender

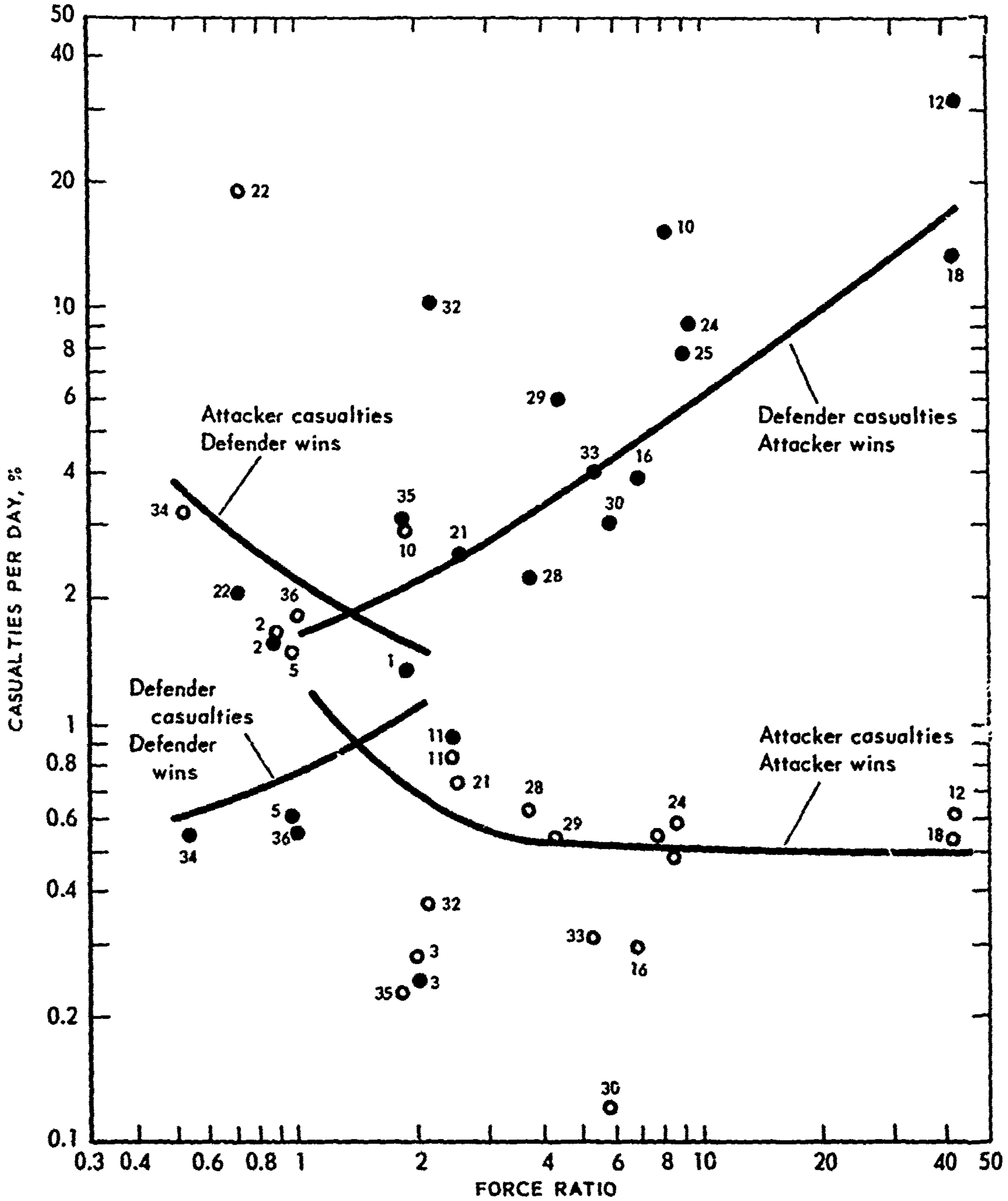

Fig. 5—Casualties vs. Force Ratio—Defender in Hasty Positions or Delay

Numbers refer to engagements listed in Table B-2.

o —Attacker ● —Defender

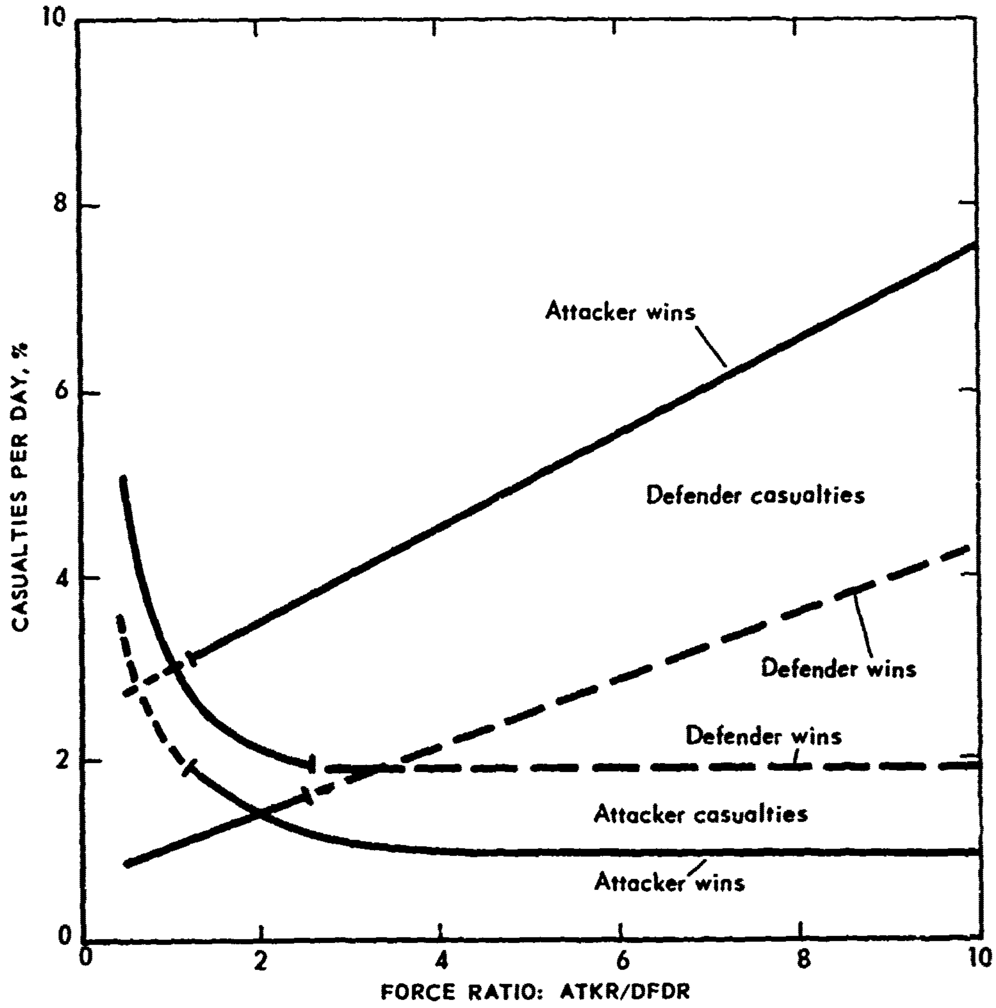

Fig. 6—Casualty Assessment Curves

Defender in fortified or prepared positions.

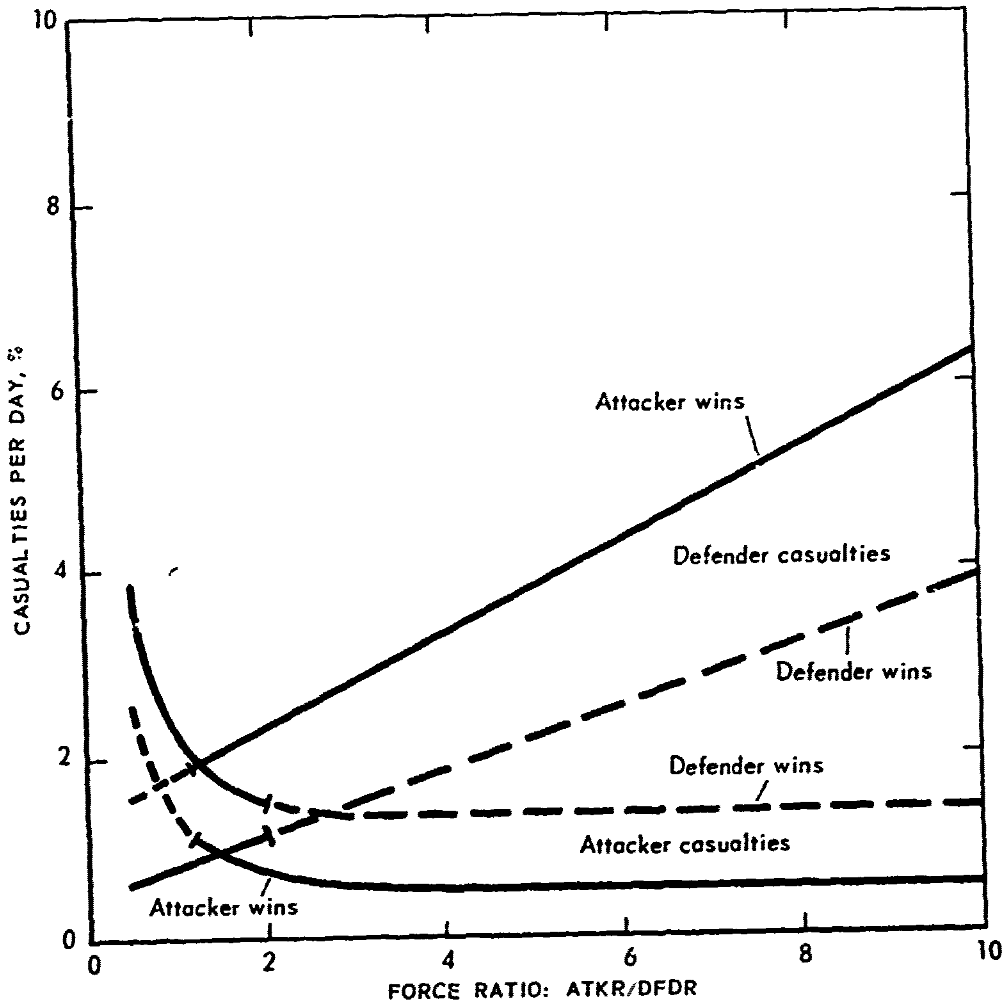

Fig. 7—Casualty Assessment Curves

Defender in hasty positions or delay.

3.3 RATES OF ADVANCE

The differing purposes and uses of the TQGM, TWGM, and DOM necessitate model differences in normal cycles of play, in unit resolution, and in some of the methodology employed in assessing results. These differences preclude identical rates of advance being employed in any two of the models if, under similar conditions, the net gains over a period of days for each of the models are to be approximately equal. To assure this compatibility, the methodology explained in App C was developed and used in determining the rates adopted for use in each of the models.

3.3.1 Derivation

The rates used in the models are based on division rates of advance per day taken from RAC-TP-76*, January 1963, and on battalion rates of advance per hour derived from CONARC War Gaming Manual, 1957**. Both documents considered historical data. The compatibility of the division rates of advance per day with the battalion rates of advance per hour was established through the methodology explained in App C. Rates which were not compatible were revised before determining the rates to be employed in each of the three models.

3.3.2 Differences Between the TQGM and TWGM Which Have an Impact on Rates of Advance

The TQGM and the TWGM employ division rates of advance per day. The ground combat division is employed by both as the unit of resolution. However, the cycle of play and the methodology for assessing results differ for the two models. The TQGM plays a phase of operations usually consisting of at least several days. The TWGM plays a normal cycle of play covering a 24-hour battle period. In the TQGM, the force ratio determines whether or not an advance is made. Probability of success factors are not played. In the TWGM, after each cycle of play, the success or failure of the attacker is determined by a probability of success factor and the draw of a random number.

* Research Analysis Corporation, "Quick Gaming (U)," RAC-TP-76, Jan 1963. SECRET

**Headquarters Continental Army Command, "War Gaming Handbook (U)", Sept 1957. SECRET

3.3.3 Differences Between the DOM and the Other Models Which Have an Impact on Rates of Advance

The DOM employs battalion rates of advance per hour, plays the battalion or company as its unit of resolution, and usually limits its cycle of play to from one to three hours. Also, the model refines its play of some defensive postures to a greater extent than the other models.

3.3.4 Establishing Compatibility Between the TQGM and TWGM Rates

The compatibility of the rates in the two models is determined by dividing the TQGM rate, or by multiplying the TWGM rate, by the appropriate probability of success factor employed in the TWGM. This methodology is illustrated and explained in para 2, App C.

3.3.5 Establishing Compatibility Between DOM Rates and Those in the Other Models

The methodology for comparing the DOM rates with those of the other models is based on certain assumptions and differs for some of the defense postures. Assumptions are made pertaining to the depth of a battalion's organized defenses, ratio of daylight movement to night movement, and number of hours in a 24-hour period during which battalion rates of advance might be expected to apply. The assumptions are discussed, and the methodology for comparing DOM rates with those of the other models is explained and illustrated, in para 3, App C.

Chapter 4

MAINTENANCE

4.1 GENERAL

When war gaming documentation is published and distributed, after a period of time the question as to the current accuracy and applicability of the models is certain to be raised in the minds of the users. It has been found at RAC that war gaming models are never static and frequently changes are made from one application to the next. The problem thus arises as to the steps that should be taken to maintain TBM-68 in a current status.

Examination of this problem indicates that requirements for revision and updating may be generated from three sources.

Initial user application of the models to operational planning problems may reveal deficiencies in model logic, input data requirements, excessive time requirements for play, and other defects that had not been anticipated by the model authors.

The organization of units, types of weapon systems, effects of munitions, or other data that were inputs to the calculation of the Indexes of Firepower Potential may change.

Major improvements or changes in concepts in the art of war gaming may occur.

4.2 INITIAL APPLICATION

In anticipation of the possibility that the initial use of the TBM-68 models may disclose requirements for revisions in the models, a system for submission of comments on the initial applications of the models should be established. It is suggested that the JWGA request the other users of the war gaming manuals to submit comments and recommendations for revision after the models have been put to sufficient use to indicate that changes are desirable.

4.3 CHANGES IN ORGANIZATION AND WEAPONS

RAC was given guidelines for determination of the organizations and weapons systems that should be considered in the Index of Firepower Potential calculations. The general criterion was that weapons and equipment that had been standardized and were in the hands of troops in January 1968 would be included. Standard TOEs as of the same date would be used for unit organizations. Some exceptions to this policy were made. Notably the F-111 aircraft was included although it was not scheduled for deployment until somewhat after that date. A projection was also made for one of the aircraft attributed to the Red side.

The identification of 1 January 1968 as the general cut-off date for consideration of organizations and weapons establishes a requirement for routine review of changes in organizations and new weapons (and new information concerning weapon effects) that would warrant the recalculation of the IFPs.

It is suggested that the JWGA establish an annual (or biennial) review procedure to consider this problem and to prepare changes to the IFP tables as required.

4.4 IMPROVEMENTS IN THE ART OF WAR GAMING

The details of the models and submodels of the TBM-68 gaming manuals are, of necessity, based on the knowledge of the authors concerning the state of the art of war gaming at the time of writing. It is possible that major changes or improvements in the art of war gaming will occur. New information about the performance of military units in conflict situations may be developed. Developments from these sources and other innovations in the techniques and procedures of war gaming may be the basis of revisions in the TBM-68 documentation.

It is suggested that the review procedure, discussed above, established to consider changes in organizations and weapons also explictly consider the developments in the art of war gaming that would warrant revisions of the TBM-68 documentation.

4.5 REVISION OF TBM-68

When the requirement for major revision of TBM-68 is recognized. it is recommended that the JWGA establish a project, similar to the present project, to accomplish the necessary revision.

Chapter 5

CONCLUSIONS

5.1 GENERAL

After reviewing the literature on war game models, submodels and routines, it is concluded that the state-of-the-art permits valuable and useful gaming to be conducted. But in no area of military operations are the available concepts and data completely adequate. Some areas are especially weak and are discussed below. They fall under the heading of: weapon firepower scores, unit combat effectiveness, use of force ratios, logistics, nuclear fire operations, and the simulation of tactical decision.

5.2 WEAPON FIREPOWER SCORES

Although the present exclusive reliance on firepower to measure unit combat effectiveness must be drastically amended, sight should not be lost of the fact that there will be a continuing requirement to associate firepower scores with individual weapons. It is concluded after review of App A of Vols I-V, that the current firepower score calculations are especially weak in the following areas: the calculation of tank firepower scores on a basis commensurate with the infantry firepower scores; the calculation of the antitank scores of infantry weapons; and the calculation of the firepower scores to be associated with close air support sorties (CAS). This latter raises very difficult questions as to whether the target location accuracy and vulnerability of targets for CAS is as comparable to those for artillery as is assumed here. In other words, it is controversial whether the intelligence and vulnerability of targets for the CAS should be the same as is assumed for artillery targets. This is the effect of equating the effectiveness of the lethal area of artillery munitions with the effectiveness of the lethal area of CAS munitions. Thus it could be quite important if what the pilot sees is more or less accurate, and more or less vulnerable, than what the forward observer for an artillery unit sees.

Perhaps as troublesome as the CAS firepower score is the effectiveness (firepower score) of a tank. One knows that there are important distinctions between a tank and an infantry unit. There is the problem of vulnerability. What value should be assigned a tank machine gun as compared to an infantry machine gun? Clearly their combat effectiveness is not the same. Another question involves the limitation on the field of view

of a tank-mounted machine gun or antitank weapon as compared to the unlimited field of view of infantry-manned weapons. It is concluded that a fair and equitable measure of the effectiveness of tank-mounted weapons, as compared to infantry weapons, is not now in hand, although the work done on tank-infantry trade-offs (App A) is a start.

The problem of determining the firepower score of an infantry antitank weapon is related to the points raised above. To put it succinctly, the value of an antitank weapon is related to the value of the tank it attacks. Yet the firepower score of a tank is uncertain, depending, as it does, on the mobility and vulnerability of the tank. The quality of these attributes of a tank clearly distinguish it from a small-infantry unit.

5.3 UNIT EFFECTIVENESS

The question as to what the firepower score of various weapons should be does not exhaust the subject. In highly aggregated games — the TQGM for example — the present system simply sums the firepower scores of the TOE weapons. No matter how sophisticated is the calculation of the firepower of individual weapons, the system will be inadequate, since the other properties of the unit containing the weapons are not taken into account. It is concluded that considerable research which seeks to establish the combat value of all the attributes of a unit is justified. Such attributes include: unit mobility, both in and out of battle; unit intelligence gathering capabilities; unit response; and planning times as a function of the command-control-communications capabilities and the limitations imposed by logistical constraints. It is also concluded that an effective approach to this problem will involve appropriate games and simulations. For example, the properties of a division (i.e., the combat effectiveness of a division) for use as input to a theater-level game should be investigated with a division-level game, or if available, a division-level simulation. Similarly, the properties of the companies and battalions which maneuver in a division-level game should be determined by study of games, or preferably simulations, at the company and battalion level.

Such work will be expensive in time and manpower, but the utility and the need for valid and reliable war games and simulations are so high that much work is justified.

5.4 USE OF FORCE RATIOS

Once the combat effectiveness has been determined it will continue to be used for the calculation of a force ratio, that is, the ratio of the combat effectiveness of the opposing forces. That calculation will be meaningful only if valid conclusions can be drawn from it. In particular there are two consequences of battle at a certain force ratio, namely the rate of advance and the casualties as the battle progresses. In this technical report, we report on a small effort to establish at the division level, daily casualties (App B). This effort must be expended to include many more historical situations in order to provide data of sufficiently general nature.

Work must begin to establish the dependence of rates of advance on force ratios, by reference to history and also to appropriate low-level simulations.

5.5 LOGISTICS

The logistical structure for the play of logistics as such is straightforward. It can, of course, be quite tedious and resource consuming. However the movement, stockpiling, and consumption can all be readily handled. What is not clear is (1) the effect of rationing on the combat effectiveness of a combat unit, and (2) the effect of spending larger than normal quantities of ammunition, in short, the effect of variations in the Estimated Expenditure of Ammunition (EEA).

It is concluded that work on logistic models should emphasize the direct interaction of logistics with combat effectiveness in the terms listed above.

5.6 NUCLEAR FIREPOWER

A great deal of study has gone into the problems associated with the use of nuclear weapons on the battlefield, that is, in the tactical role. This work from the beginning has been hampered by the lack of good information in two areas: (1) the target location errors and (2) the casualty effects of thermal radiation.

To be specific about target location errors, the usually used estimates of errors in the location of the center of mass of a target unit are quite a bit lower than those shown by an historical study.* Consideration

*Combat Operations Research Group, HQ CONARC, unpublished memorandum, 1960.

of the usual confusion and incorrect information so common on the battlefield leads to the conclusion that precise target location would be rare. It is concluded that a substantial effort, involving both historical studies and realistic field tests, is required before the estimates used in war games can be considered adequate.

With regard to the second point, inadequate attention to thermal casualties, the reason for the difficulty is clear. Thus Army nuclear weapon staff members are expected to estimate "assured casualties." But the thermal effects are so variable, no great assurance can be placed on them. Consequently, the casualty potential discussed in the Army Nuclear Effects Handbook tend to ignore thermal effects. However, for the larger yield weapons that have been considered for use on the battlefield—the thermal effects may be very significant. It is concluded that study of this effect is required in order to improve the estimates of nuclear casualties used in war games.

5.7 SIMULATION OF TACTICAL DECISION

Consider the ideal war game/simulation. It would be capable of operating in two modes: what might be called the "semiautomatic" and the "full automatic" modes. In both cases all the assesment would be carried out by a computer. The thing that distinguishes these two modes is how the tactical decision procedure is handled.

In the semiautomatic mode, the computer would be programmed to conduct routine assessments for a stated period and then stop and present the current situation to a decision maker (i.e., one of the players). Using appropriate hardware the decision maker would decide whether he wished to interject a new order, or allow the computer to proceed using its own tactical decision subroutines. (The input/output hardware to implement this concept is already in existence.)

In the full automatic mode, the players would forego the option of interrupting the computer, allowing the computer to process the entire campaign automatically from beginning to end. The benefit from operating in the full automatic mode is at least substantial, if not enormous. The great speed of play permits numerous repetitions of the campaign to be conducted. Thus the sensitivity of the results to the numerous input assumptions — including, of course, the general and special situations — may be determined.

Now in the normal case, both of these modes of operation require the computer to make sensible and realistic tactical decisions. On semiautomatic, the computer must make routine decisions covering the

intervals between interruption by the players; on the full automatic, the computer makes all the tactical decisions.

Games (simulations) are already in existence which incorporate tactical decision routines.* However, the simulation of the tactical decision process is rudimentary. It is concluded that the state-of-the-art of gaming will not yet permit adequate decision routines to be written without much additional study of the logical structure of this process. A high priority for such study is justified.

5.8 SUMMARY

In summary it is concluded that significant improvement in the realism of war games can only follow from intensive work in the following areas:

Firepower Scores
Unit Combat Effectiveness
Use of Force Ratios
Variable Ammunition Expenditure Rates
Nuclear Target Location Errors
Thermal Radiation Casualty Potential
Simulation of Tactical Decision

*RAC's Computerized Quick Game and the Army War College's MACE

Appendix A

INFANTRY-TANK TRADE-OFFS IN SMALL UNIT ENGAGEMENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 Purpose

The research was undertaken to determine infantry-tank trade-offs and the associated firepower score by using CARMONETTE,[1] a small unit ground combat computer simulation.

1.2 Background

As do war games generally, the TBM-68 family of war game models computes the casualties and rates of advance from consideration of a "force ratio." The force ratio is computed from firepower scores associated with the units on each side. The firepower scores represent a casualty potential and are based on historical data giving weapon effectiveness, lethal areas, and estimated ammunition expenditure rates. The historical data is clearly only relevant if the combat is of WW II and Korean type — in terms of weapons, tactics, and doctrine. Thus, if the character of the battle is changing — utilizing new weapons, tactics, and doctrine — then the firepower score, so computed, becomes an inadequate representation of the characteristics and capabilities of the unit.

This deficiency has long been recognized. Nowhere is the firepower score concept more difficult to apply then in describing the effectiveness of tanks. Historical data describing the utilization of the tanks' weapons against infantry are almost totally lacking. Yet the numbers of tanks available for use on future battlefields are substantially larger than in past wars.

The work described herein will not of itself improve the firepower score system, since it constitutes only part of what must be done. Nevertheless, it is an effort to take the measure of a tank in the context of battle, at least for the situations studied, using the detailed simulation of combat, CARMONETTE. Within the limits of time and money, only one tactical situation — assault of a hasty position — could be investigated.

The results of this work give a better basis for computing the trade-offs of tanks against infantry platoons and thus yield directly new firepower scores for the tank which are worthy of careful attention by those who must determine and use a system of firepower scores.

The research described in this appendix is a continuation of a research task sponsored by the US Arms Control and Disarmament Agency (ACDA) for which the principal investigator was Mr. Lewis A. Leake.* After initiation of the ACDA study, mutual interests of the ACDA study were established with the research planned in connection with the Theater Battle Model-68 (TBM-68) for the Joint War Games Agency (JWGA). Primarily the ACDA study was methodology. The research for TBM-68 was for improvement of firepower scores. This difference of goals required revision of the input data to be as realistic as possible in addition to being representative of combat. The modification of input data concerned such factors as hit probabilities and kill probability of specific weapons and provided a stronger foundation for the input data. The potential results of the ACDA study thereby became relevan to the research for JWGA, and close cooperation was established between the two studies.

1.3 Scope

Against a given defender force mix of infantry and tanks, a number of CARMONETTE[1] simulations involving varying attacker force mixes were conducted. By varying the number of tanks in the attacker force mix for one level of infantry, it is possible to find a curve of probabilities of mission success for an attacker as a function of the number of tanks in the attacker force mix. Mission success for the attacker is defined in this simulation as occurring when the defender force suffers 50 percent casualties before the attacker force has suffered 40 percent casualties. Conversely, a defender win or attacker loss is declared when the attacker force suffers 40 percent casualties before the defender force has suffered 50 percent casualties. Emphasis was given to conducting simulations over a range of attacker force mixes to establish attacker force mixes for which the probability of mission success of the attacker (or defender) is 0.5. (The probability of mission success being denoted as 0.5 is synonomous to the outcome of a "stand-off," or "draw," or a "stalemate.")

Investigating simulations of each and every attacker force mix was not necessary because of the goal of establishing empirically a 50 percent probability of success level of force mixes. In some cases quantities of tanks excessively large (as resulting from CARMONETTE restrictions) were required for establishment of the 50 percent mission success. In contrast to the above, the strength of attacker infantry force alone may yield empirical mission success greater than 50 percent. As mentioned above, various attacker force mixes and a specific defender force mix were simulated.

*Frequent references to the document are made in this appendix. (For example, the vast quantity of input data is given in tabular form in Ref 2. No efforts are made to reproduce the input data here.) Certain game results reported herein are synonomous with those reported in Ref 2.

In the initial simulations the effect of artillery was found to be significant to the extent of possibly overshadowing the primary purpose of the research. Therefore the effects of varying rate of fire of artillery were investigated with the initial defender force mix. Several variations of artillery rate of fire were considered for the purpose of determining the sensitivity of the trade-offs to the spectrum of attacker infantry and tanks investigated.

For each defender force mix, analysis of the simulation results established attacker infantry families of mission success probability curves as a function of the number of attacker tanks. Thus constant effectiveness trade-offs of attacker infantry and tanks were determined for several defender force mixes and artillery rates of fire.

By no means do the present results pretend to be exhaustive. It must be remembered that the results of this research are relevant only to the conditions tested, for example, terrain, tactics, doctrine, and scenario, and of course, the validity of the CARMONETTE simulation itself.

2. CARMONETTE SIMULATION

2.1 General

CARMONETTE[1] is a Monte Carlo computer simulation of ground combat. Using a predetermined scenario and detailed input data, CARMONETTE simulates the important aspects of small unit combat of movement, target acquisition, weapon firing, and target kill.

A discussion of the detailed input data, including unit descriptions, detection probabilities, weapon characteristics, hit and kill probabilities, preferred target lists, terrain, and unit orders, is presented in Ref 2. CARMONETTE simulates an intense combat phase of 20-40 minutes duration. It presently operates on an IBM 7044 computer. Computer termination of the simulation occurred when one side or the other had won as defined above.

Since the simulation is probabilistic, of utmost importance is the CARMONETTE capability of repetition, that is, specific battles of distinct force mixes may be simulated any number of times with the outcome differing, one from the other, depending only on the play of chance. The attribute of repetition enables a homogeneous sample to be obtained and subsequent statistical analysis to be performed.

2.2 Scenario

The scenario of the simulation is briefly described as follows. The defender force consisted of units representative of a reinforced infantry rifle company with artillery in support. The defender force is occupying positions on one of a series of hastily prepared defensive positions. (Only one of several small unit engagements is being simulated.) Within platoon positions riflemen are occupying or sharing two-man positions with automatic rifles, grenadiers, or machine guns and are disposed so as to afford maximum close-in protection to supporting crew-served weapons. All positions are protected by at least one wire barrier placed generally along the final protective line.

The attacker force consisted of units representative of a reinforced motorized rifle battalion combat team with artillery in direct support. A scheduled artillery preparation is fired prior to the attack. The main attack is on the north and a supporting attack on the south (see Fig. A-1). Mechanized units, supported and preceded by attached tanks, advance as rapidly as possible

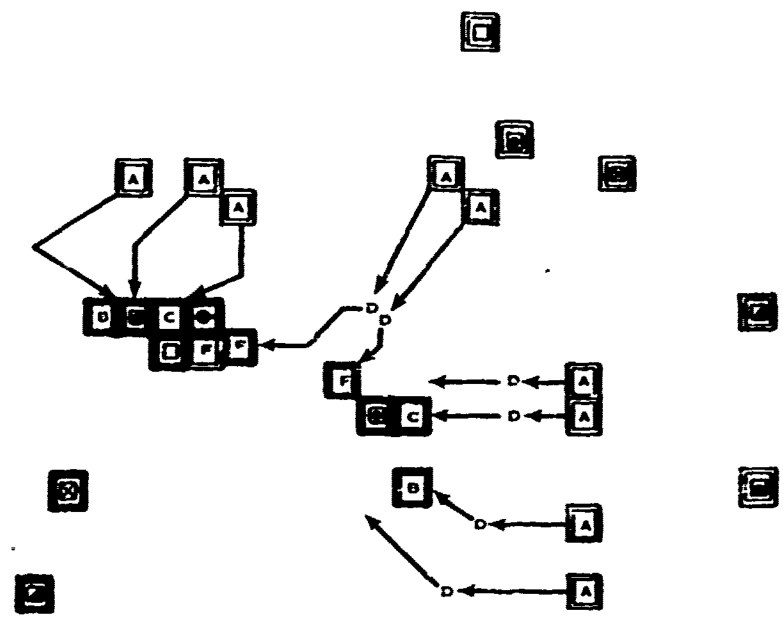

Fig. A1—Deployment of Initial Defender Force Mix and Attacker 9 Infantry Platoon–9 Tank Force Mix

Defender forces	Antitank gun or rckt lchr (AT) squad
D Dismount point	B Tank & inf squad
Attacker forces	C Wpns squad
A Tank, APCs & inf platoon	F Inf squad
ATGM	AT squad
4.2 in. mortar	Prescribed unit movement
81 mm mortar	

until rifle units dismount. Dismounted infantry, supported and preceded by tanks and supported by carrier weapons, will attack, assault and capture objectives.

The make up of the defender units and their weapons is in accord with the ROAD TOE. The attacker force is organized to match present estimates of Soviet mechanized forces but has US weapons.

2.2.1 Forces Simulated. The various combinations of defender and attacker force mixes considered will be generally described first. Secondly, a more detailed description of the base case and subsequent cases will be given.

Four combinations of mixes of tank-infantry forces were simulated as defender forces. The number of infantry platoons and of tanks varied from one to three in the defender force mixes. The series of simulations of defender force mixes were conducted in the order shown in Table A-1.

Table A-1

DEFENDER FORCE MIXES

Series	Infantry platoons	No. of tanks
1	2	2
2	1	3
3	3	1
4	2	3

In opposition to each defender force mix a variety of attacker force mixes were designed as shown in Table A-2. Infantry strength varied from 2 to 9 infantry platoons. Armor strength varied from no tanks to as many as 17 tanks. The range of number of tanks simulated in specific simulations using attacker force mixes of constant infantry strength was to some degree determined by the relative strength of the defender force. In no cases were simulations conducted for all possible combinations of attacker force mixes. Also the limitations of CARMONETTE imposed maxima. For example, when the attacker force mix was comprised of 9 infantry platoons, no more than 9 tanks could be simulated due to the CARMONETTE limitation on the number of units simulated.

Table A-2

ATTACKER FORCE MIXES

Infantry platoons	Number of tanks
2	0 - 17
3	0 - 11
4	0 - 16
5	0 - 17
6	0 - 11
7	0 - 11
8	0 - 9
9	0 - 9

2.2.2 Base Case. The first series of CARMONETTE battles simulated a defender force of 2 infantry platoons and 2 tanks. The composition of the defender force is given specifically in Table A-3.

Both defender and attacker artillery rate of fire was varied by adjusting the artillery reload time. Initial simulations used a 1.2 min reload time. The second set used a 0.6 min reload time. The last set of simulations was conducted with an artillery reload time of 0.9 min. Thus, three artillery rates of fire were investigated — 0.83 rds/min, 1.11 rds/min, and 1.67 rds/min.

A variety of attacker force mixes were simulated against the defender force. The composition of the units comprising the attacker force mix of 9 infantry platoons and 9 tanks is given in Table A-4.

The deployment of the initial defender force mix and attacker 9 infantry platoon — 9 tank force mix is shown in Fig. A-1. As the attacker infantry platoon strength was lowered, precedence was given to attacking the defender right flank. The various modifications of attacker force mixes were deployed on the basis of judgment of experienced military personnel. For specific details regarding the deployment of the modified attacker force the reader should consult App C of Ref 2.

Table A-3

DEFENDER UNITS COMPOSITION

Unit	Personnel (ea)	Vehicles (ea)	Weapons (ea)
2 Rifle platoons	44	--	
(3 Rifle squads)	11	--	5 7.62-mm rifles (M14) 2 7.62-mm auto rifles 2 40-mm GL 1 50 cal MG*
(1 Weapon squad)	11		
(AT section)	4	--	2 90-mm RR 1 7.62-mm rifle (M14)
(MG section)	7	--	1 50 cal MG* 2 7.62-mm MG 1 7.62-mm rifle (M14)
1 81-mm Mortar section	10	1	2 81-mm mortars
1 4.2-in. Mortar squad	5	1	1 4.2-in. mortar
1 Antitank section	12	3	
2 AT squads	4	1	1 106-mm RR 2 7.62-mm rifles (M14)
1 ENTAC squad	4	1	1 ENTAC 3 7.62-mm rifles (M14)
2 M60 Tanks (US)	4	1	1 105-mm MTG 1 50 cal MG 1 7.62-mm MG
1 155-mm Howitzer battery	63	--	6 155-mm Howitzers

*Emplaced for defense from APC.

Table A-4

SAMPLE ATTACKER UNIT COMPOSITION

Unit	Personnel (ea)	Vehicles (ea)	Weapons (ea)
9 Rifle platoons when mounted	32	2	2 50 cal MG 4 7.62-mm MG
when dismounted	28	--	3 3.5-in. Rkt lchrs 4 7.62-mm MG 20 7.62-mm rifles (M14)
1 81-mm Mortar section	15	--	3 81-mm mortars
1 4.2-in. Mortar section	10	--	2 4.2-in. mortars
2 Antitank gun sections	7	1	1 90-mm AT gun
3 ENTAC squads	3	1	1 ENTAC
9 M60 tanks (Soviet wpns)	4	1	1 105-mm MTG 1 7.62-mm MG
1 155-mm How Btry	63	--	6 155-mm Howitzers
2 105-mm How Btrys	63	--	6 105-mm Howitzers

2.2.3 Commensurate Support Fire. Varying the number of infantry platoons and tanks in the attacker force mix was accomplished merely by either adding or deleting infantry platoons and/or tanks in the simulation. However, to provide for commensurate fires from supporting weapons, adjustments of the support units composition, and in some cases, adjustments in the probability of kill given a hit P (K/H) for the specific weapon were necessary. The maximum attacker infantry strength of 9 platoons was supported by one unit of three 81-mm mortars, one

unit of two 4.2-in. mortars, two units of one 90-mm gun each, and three ATGM units of one ENTAC each. The commensurate level of support (in decreasing infantry strength by decrements of one platoon) required proportional scaling as given in Table A-5. Modification of input data (i.e., the combination of units, weapons per unit, and scaling factor of P (K/H)) yielded commensurate fires from supporting weapons. For example, the reduction of infantry support fire from support weapons for 9 platoons to the appropriate support for 6 infantry platoons requires a decrease of support fire by 1/3 — namely deletion of one 81-mm mortar from the unit of three 81-mm mortars, deletion of one unit of ATGMs from 3 units of ATGMs, and the adjustment downward of the P (K/H) of the 4.2-in mortar by the factor of 0.67.

2.2.4 Artillery. Artillery fire was not adjusted as a function of the strength of attacker infantry. Since the primary purpose of the research was aimed towards determining the infantry-tank trade-off, the scaling of artillery relative to infantry strength would have confounded the primary infantry-tank effect. However, in order to appraise the effects of artillery, it was varied for one of the defender strengths. As will be seen, this variation did not obscure or radically alter the tank-infantry trade-off.

The scheduled attacker artillery fires were terminated on the arrival of attacker units in terrain adjacent to artillery impact areas. Only in the cases where the attacker infantry strength was reduced to two platoons did the artillery impact areas change. In this case artillery fire was scheduled on areas to distract defender fire from the right flank of the attacker but with little or no difference in the outcome. For further discussion and details as to the specific units involved, consult App C of Ref 2.

2.2.5 Other Defender Force Mixes. Modifications to the initial defender force mix were made and resulted in the other defender force mixes investigated. After completion of the simulations involving the 2 infantry platoon — 2 tank defender force mix, the force mix of 1 platoon and 3 tanks was established for the defender. From the initial defender force, one infantry platoon (3 rifle squads and 1 weapon squad) was deleted and one tank was added. In addition, the infantry support fires were decreased by one-half. This was accomplished by reduction of the probability of kill to one-half of its initial value for the 81-mm mortar, for

Table A-5

ATTACKER FORCE ADJUSTMENTS TO PROVIDE COMMENSURATE FIRES FROM SUPPORTING WEAPONS

Infantry platoon strength	81-mm Mortar Units			4.2-in. Mortar Units			AT Gun Sections			ATGM Sections		
	Units	Wpns	Factor[a]	Units	Wpns	Factor[a]	Units	Wpns	Factor[a]	Units	Wpns	Factor[a]
9	1	3	1.00	1	2	1.00	2	1	1.00	3	1	1.00
8	1	3	0.89	1	2	0.89	2	1	0.89	3	1	0.89
7	1	3	0.78	1	2	0.78	2	1	0.78	3	1	0.78
6	1	2	1.00	1	2	0.67	2	1	0.67	2	1	1.00
5	1	2	0.82	1	2	0.56	2	1	0.56	2	1	0.83
4	1	2	0.67	1	1	0.89	1	1	0.89	2	1	0.67
3	1	1	1.00	1	1	0.67	1	1	0.67	1	1	1.00
2	1	1	0.67	1	1	0.47	1	1	0.44	1	1	0.67

[a] Factor by which P (K/H) is scaled.

the 4.2-in. mortar, and for the ENTAC and the deletion of one of the two AT squads (see the tabular listing of the intial defender force given in Table A-3). These modifications provided for commensurate fires from support weapons. To further take into account the reduced strength of the defender infantry force, the deployment of the defender units was modified as shown in Fig. A-2.

Two other defender force mixes were simulated. The third defender force mix consisted of 3 infantry platoons and 1 tank. The addition of 1 infantry platoon, the deletion of 1 tank and adjustments for commensurate fires from infantry support weapons were made to the initial defender force to set up the 3 platoon — 1 tank defender force. The force mix of two infantry platoons and three tanks was established by the addition of one M60 tank to the initial defender force. Deployments of these defender forces also were modified and are shown in Figs. A-3 and A-4.

The defender artillery strength was not changed relative to changes in the defender infantry-tank force mix. The same rationale as previously stated in regard to variable attacker force strengths applies here.

Only in the base case did the artillery vary. As described earlier, several artillery rates of fire were investigated in the base case. In the simulations conducted for the other defender force mixes, the rate of fire of artillery was 1.11 rds/min (i.e., reload time 0.9 min). The 1.11 rds/min rate of fire was selected as being the most reasonable of the three rates.

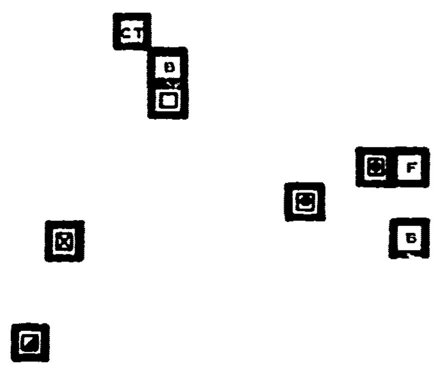

Fig. A2—Deployment of Defender Force Mix of 1 Infantry Platoon and 3 Tanks

Defender forces AT squad ATGM 81 mm mortar

4.2 in. mortar B Tank & wpn sq C Weapon sq F Inf sq T Tank

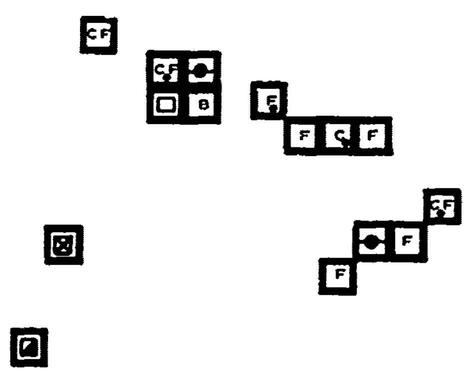

Fig. A3—Deployment of Defender Force Mix of 3 Infantry Platoons and 1 Tank

Defender forces ● AT (rckt lchr) squad ATGM 81 mm mortar

4.2 in. mortar B Tank & inf sq C Wpn sq F Inf sq AT sq

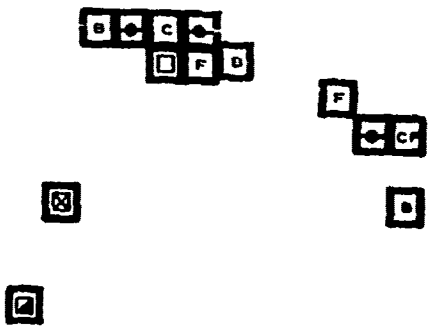

Fig. A4—Deployment of Defender Force Mix of 2 Infantry Platoons and 3 Tanks

Defender forces — AT squad — ATGM — 4.2 in. mortar

81 mm mortar — B Tank & inf squad — C Wpn squad — F Inf squad

3. TECHNIQUES OF ANALYSIS

For each defender force mix, a mathematical model was fitted to the simulation outcomes. The model established attacker infantry families of mission success probability curves as a function of the number of attacker tanks. A family of curves was established for each defender force mix. The model*

$$P_s = (1 + e^{-Z})^{-1}$$

where $Z = f$ (attacker infantry, tanks),

P_s = probability of mission success for the attacker;

was assumed as a functional representation for a single defender force mix. For the initial defender posture (i.e., 2 infantry platoons and 2 tanks) the rate of fire of artillery was investigated. For this defender force mix, the value of Z was defined as a function of artillery rate of fire as well as infantry platoons and tanks.

Empirical observation of the outcomes of the simulations conducted against one defender force mix were input to the model. The observations were considered as a two-valued variable, one or zero, depending upon the outcome of a simulation. An observation of one was considered as an attacker win, zero as attacker loss; each observation is an independent measure from one combination of independent variables — attacker infantry platoons and attacker tanks and, for the base case, artillery rate of fire.

As many as six different combinations of artillery rate of fire, attacker infantry, and tanks in the base case were considered as the function Z. In addition cross products of the independent variables were investigated such as:

$$Z = a_1 + a_2R + a_3I + a_4T + a_5RI + a_6RT + a_7IT,$$

$$Z = a_1 + a_2R + a_3I + a_4T + a_5\sqrt{RI} + \dots + a_7\sqrt{IT},$$

*This model was developed by Dr. Strother Walker at Johns Hopkins University in connection with his doctoral dissertation on coronary illness.[3] The model was later computerized, with an improvement in the initial estimation of the coefficient vector of Z.

$$Z = a_1 + a_2R + a_3I + a_4T^2, \text{ etc.}$$

where R = artillery rate of fire
I = number of attacker infantry platoons
T = number of attacker tanks
a_i = coefficient of the independent variable.

For the other defender force mixes, fewer combinations of Z were investigated without, of course, the consideration of artillery rate of fire.

A measure of goodness of fit of the regression equations in comparison with the input data is available. The Students-t test was used to test the significance of each coefficient (that is, its difference from zero) by comparing the estimate of the standard deviation of the regression coefficient with the value of the coefficient.

The results of the model fitting produced attacker probability of success (as defined above) as functions of attacker mix. Each attacker infantry platoon strength was represented by a probability of success curve. Against one defender force mix, the several curves were defined as a family. From such a family of curves, each representing a specific attacker infantry strength, the attacker force mix required for a constant probability of success was obtained. The force mixes for constant success for several infantry strengths produce the trade-offs for infantry platoons and tanks. In this research, the constant probability of success was taken to be 0.5.

4. RESULTS

4.1 Simulations Conducted

A total of 986 CARMONETTE simulations were conducted and served as the data base for this research. Table A-6 gives a breakdown of the simulations relative to each of the four defender force mixes investigated. As shown in Table A-6, the number of simulations conducted for the various defender force mixes, and for the several artillery rates of fire in the base case, differed considerably. As was stated earlier, in no case were all possible combinations of attacker force mixes simulated. An effort to center the simulations near the approximate isoeffectiveness force mixes (0.5 probability of success) reduced the combinations of attacker force mixes investigated.

Table A-6

CARMONETTE SIMULATIONS CONDUCTED

Defender		Arty rate of fire (rds/min)	Attacker force mix combinations investigated	Simulations conducted
Inf plats	Tanks			
2	2	1.67	41	150
2	2	1.11	45	177
2	2	0.83	11	29
2	2	No arty	5	5
1	3	1.11	34	199
3	1	1.11	25	138
2	3	1.11	39	276
2	3	No arty	2	12

A further breakdown of the totals of Table A-6 is given in Table A-7. The outcome of each simulation conducted was recorded as an attacker win or an attacker loss (as defined in the Scope and TECHNIQUES OF ANALYSIS sections of this paper). Table A-7 lists these results of attacker wins and the number of simulations conducted for the specific attacker force mixes investigated. The enumerations follow the same presentation order as in Table A-6. These data are the input to Walker's model, $P_s = (1 + e^{-Z})^{-1}$.

The results of Walker's model are presented for the four defender force mixes in the same order as Table A-6 and A-7. Differing combinations of independent variables (artillery rate of fire, attacker infantry platoons, attacker tanks) were developed for Z in the model, somewhat by trial and error. However, only the curves resulting from the most significant combinations of variables are discussed. A significant combination of independent variables was determined from analysis of the coefficients that had been computed from the regression analysis or "fit" of Walker's model.

Table A-7

NO. OF ATTACKER WINS/NO. OF REPLICATIONS
(For different Attacker-Defender Force Mixes)

DEFENDER
2 Infantry Platoons-2 Tanks

Attacker tanks	Attacker Infantry Platoons							
	2	3	4	5	6	7	8	9
	Artillery Rate of Fire 1.67 rds/min							
0				0/1	0/2	5/7	3/3	1/1
1				4/5	2/3	4/5	0/1	
2				3/5	3/5	4/5	1/1	
3				2/5	3/4	3/5	1/1	
4				3/5	2/2	2/5		
5		1/2	1/5	1/5		5/5		
6		0/2	4/7	4/5				
7		1/4	2/3	1/1				
8	1/1	2/4	1/1					
9		2/3						
10		1/1						
11	1/5							
12	1/5							
13	4/5							
14	3/5							
15	5/5							
16	3/5							

Table A-7 (continued)

DEFENDER
2 Infantry Platoons-2 Tanks

Attacker tanks	Attacker Infantry Platoons							
	2	3	4	5	6	7	8	9
	Artillery Rate of Fire 1.11 rds/min							
0					0/1	2/4	2/4	1/1
1						0/1	1/2	
2				0/1		3/6		
3						2/4		
4						2/3		
5	0/1	0/1	0/1	0/5	2/5	3/5	5/5	
6				0/1	0/5	1/3		
7				0/1	3/5	2/2		
8			1/3	0/5	3/5			
9			0/3	1/5	2/5			
10			1/3	3/5	3/5			
11			2/6	2/5	2/5			
12			1/6	4/5	3/5			
13			4/6	4/5	4/5			
14			5/6	4/5				
15			6/6					
16			5/6					
	Artillery Rate of Fire 0.85 rds/min							
3								0/1
4								1/2
5						0/5	0/2	2/2
6						0/4	2/2	
7						3/4	1/1	
8						2/4		
9						2/2		
	No Artillery							
5								0/1
6								0/1
7								0/1
8								0/1
9								0/1

Table A-7 (continued)

DEFENDER
1 Infantry Platoon-3 Tanks

Attacker tanks	Attacker Infantry Platoons							
	2	3	4	5	6	7	8	9
	Artillery Rate of Fire 1.11 rds/min							
0				4/6	4/6			
1				4/6	6/6			
2			2/6	5/6	6/6			
3		3/6	3/6	5/6	5/6			
4		2/4	2/6	6/6	6/6			
5		0/3	3/6		6/6			
6	3/6	2/6	5/6					
7	6/6	3/6	4/6					
8	3/6	1/6	6/6					
9	5/6	5/6	4/6					
10	4/6							
11	4/6							
12	4/6							
13	5/6							

DEFENDER
3 Infantry Platoons-1 Tank

Attacker tanks	2	3	4	5	6	7	8	9
	Artillery Rate of Fire 1.11 rds/min							
4							0/6	1/6
5							0/6	0/6
6							0/6	0/6
7							1/6	0/6
8							0/5	0/4
9						0/1	0/6	0/6
10						0/1		
11					0/6	0/7		
12					0/6			
13				0/6	0/6			
14				1/6	1/6			
15				0/6	2/6			
16				0/6				
17				4/6				

Table A-7 (continued)

DEFENDER

2 Infantry Platoons-3 Tanks

Attacker tanks	Attacker Infantry Platoons							
	2	3	4	5	6	7	8	9
	Artillery Rate of Fire 1.11 rds/min							
0							4/6	5/7
1							3/6	3/6
2					2/6	2/6	4/6	5/10
3						2/6	5/6	4/6
4					1/6	2/6	4/10	6/10
5						6/7		
6					3/6	4/10	3/6	3/6
7					2/6	4/10		
8					3/10	5/10	2/6	
9					5/10	4/6	4/6	
10				3/6	5/10			
11				5/6	4/10	2/6		
12				3/6				
13				4/6				
14				3/6				
15				5/6				
16				6/6				
17				5/6				
9 Infantry Platoons								
	No Artillery							
8								0/6
9								1/6

4.2 Base Case

Of the several combinations of independent variables investigated for the value of Z in Walker's model, the most significant set of coefficients for the base case (defender = 2 platoons and 2 tanks) were established as:

$$Z = a_1 + a_2R + a_3I + a_4T^2$$

where a = coefficient of the i th term of Z,
R = artillery rate of fire,
I = attacker infantry platoons,
T = attacker tanks

The numerical values of the coefficients derived from the regression analysis of Walker's model established

$$Z = -8.7480 + 3.0108R + 0.6987I \quad 0.0165T^2$$

where $R = (1.67,\ 1.11,\ 0.83)$,
$I = (2,3,4,\ldots,\ 9)$,
$T = (0,1,2,\ldots,\ 16)$

Evaluation of Z for specific R, I, and T, and subsequent evaluation of Walker's model:

$$P_s = (1 + e^{-Z})^{-1}$$

yields attacker probability of success curves against the 2 platoons — 2 tanks defender force mix.

Figures A-5 — A-7 show the families of attacker probability of success curves against the 2 platoon — 2 tanks defender force mix. Each figure pertains to a particular artillery rate of fire. For each attacker infantry strength, attacker probability of success is indicated as a function of attacker tanks.

Figures A-5 — A-7 indicate that in the simulation the faster artillery rate of fire (employed by both sides) had the effect of increasing the casualty-producing strength of the attacker force mix. In other words, the faster artillery rate of fire reduced the attacker strength required to win against a

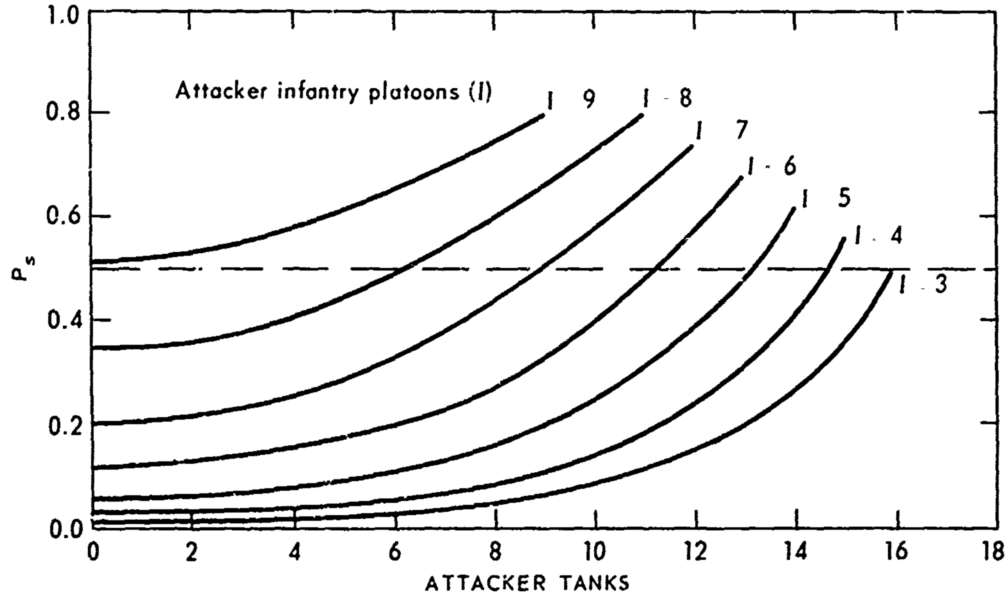

Fig. A-5—Attacker Probability of Success Curves, 2 Platoon–2 Tank Defender

Arty rate of fire = 0.83 rds/min.

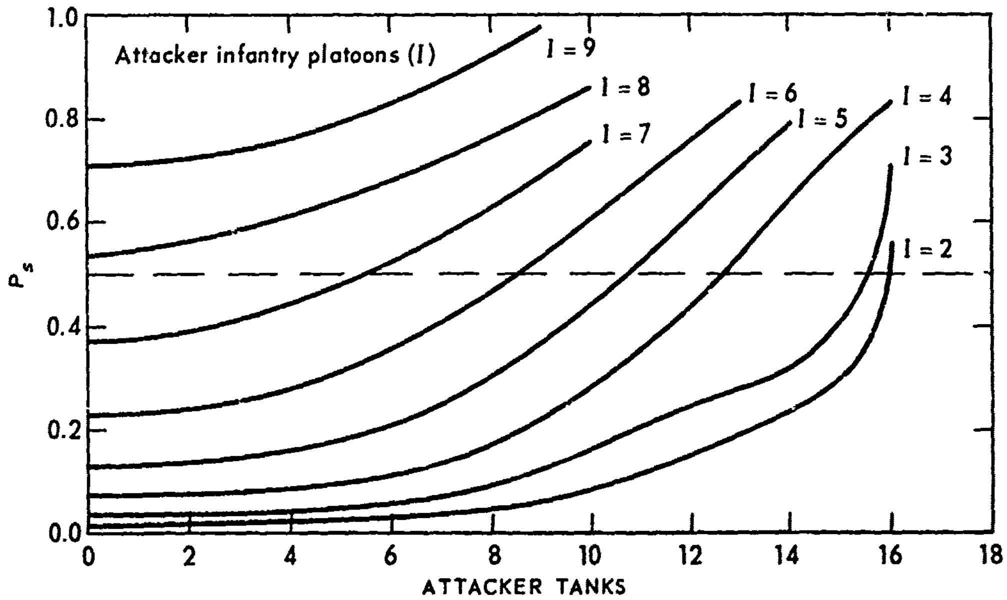

Fig. A-6—Attacker Probability of Success Curves, 2 Platoon–2 Tank Defender

Arty rate of fire ≡ 1.11 rds/min.

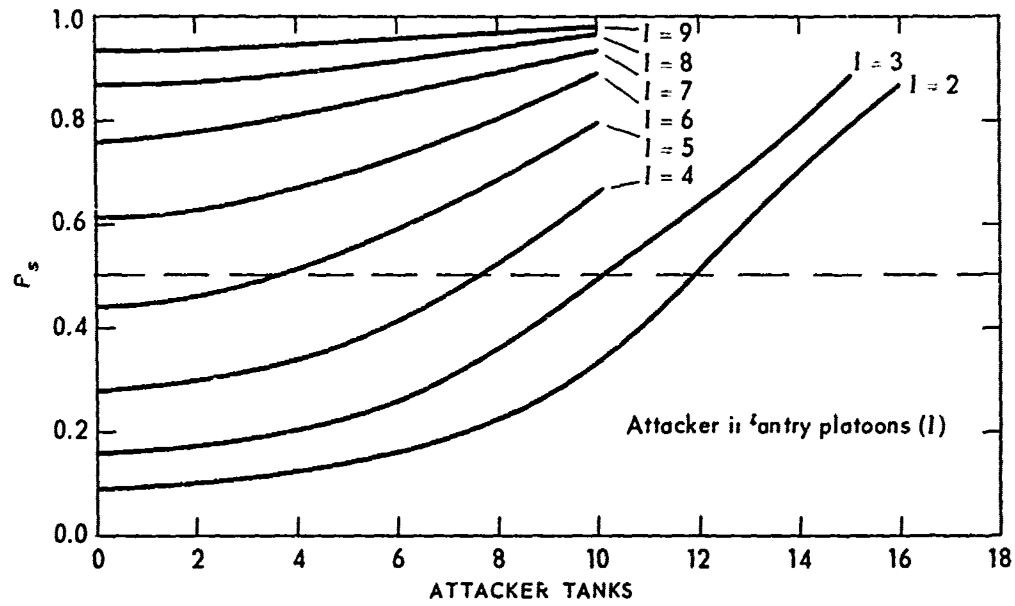

Fig. A7—Attacker Probability of Success Curves, 2 Platoon–2 Tank Defender

Arty rate of fire = 1.67 rds/min.

defender employing the same rate of fire as the attacker. This is probably a direct result of the attacker's scheduled or preparation artillery fire.*

A goodness of fit test was conducted to compare the results of Walker's model (Figs. A-5 - A-7) to the empirical data (as given in Table A-7) for each artillery rate of fire investigated. Since Walker's model yields attacker probability of success relative to the strength of attacker's tanks and infantry force for a given number of replications, and for given defender force mix, the expected number of attacker wins may be calculated. The goodness of fit testing compared the attacker's wins expected via Walker's model with the observed attacker wins from the simulations conducted. The results of the tests are given in Table A-8, and pertain to data relative to the defender force mix of 2 tanks and 2 infantry platoons.

The test utilizes the chi-square statistic which yields the probability that a given sample of observed (empirical) data may occur from an assumed mathematical model of expected values. The test addresses itself to the question, "What is the probability that a data sample such as the observed data will occur if the assumption of the model is valid?" If the probability is low, the observed data are unlikely to occur from the assumed model. Conversely if the probability is high, data from the assumed model are likely to occur as observed.

The results of interest in Table A-8 are the probabilities of occurrence of the observed data. Relative to the data pertaining to specific artillery rates of fire, it is quite likely that the observations given in Table A-7 for the cases of 1.11 and 1.67 rds/min may occur from distributions as given in Figs. A-6 and A-7. The small sample of data pertaining to the artillery rate of 0.83 rds/min is less likely to occur, thereby showing that the model does not describe the observed data as well.

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*The predetermined scenario of CARMONETTE was such that the attacker's artillery fired scheduled fires in the start of the simulation. Scheduled fire or preparation fire is artillery fire directed at a specific location on the battle field. When predesignated attacker units approached terrain adjacent to the attacker's artillery impact area, the scheduled artillery fires were terminated. From that time in the simulation, the attacker's artillery was on-call. The defender's artillery fire was on-call throughout the battle.

Table A-8

GOODNESS OF FIT TO EXPECTED RESULTS
FROM WALKER'S MODEL
(Observed Data of 2 Platoon — 2 Tank Defender)

Artillery rate of fire rds/min	Number of infantry plats	Number of tanks	Chi-Square Calculated*	Degrees of freedom	Probability of occurrence from Walker's model
1.67	2	8-16	5.228	6	.50 - .75
1.67	3	5-10	2.335	5	.75 - .90
1.67	4	5-8	1.633	3	.50 - .75
1.67	5	0-7	3.807	7	.75 - .90
1.67	6	0-4	1.625	4	.75 - .90
1.67	7	0-5	1.476	5	.90 - .95
1.67	8	0-3	16.754	3	.005
1.67	2-8		32.858	39	.75 - .90
1.11	4	5-16	3.273	9	.95 - .975
1.11	5	2-14	4.104	10	.90 - .95
1.11	6	0-13	3.723	9	.90 - .95
1.11	7	0-7	2.178	7	.90 - .95
1.11	8	0,1,5	0.963	2	.50 - .75
1.11	4-8	all	14.241	41	.995
0.83	7	5-9	5.416	4	.10 - .25
0.83	8	5-7	2.334	2	.25 - .50
0.83	9	3-5	1.207	2	.50 - .75

$$*\chi^2 = \sum_{i=1}^{k} \frac{(obs_i - exp_i)^2}{exp_i}$$

where obs_i = observed attacker wins
exp_i = expected attacker wins from Walker's model
k = number of combinations of attacker force mixes investigated

The artillery rate of fire of 1.11 rds/min was selected for further investigation of series of simulations of variable defender force mixes. It is considered to be a realistic rate, and has the virtue of being associated with attacker strengths within the limits of unit strengths which may be simulated by CARMONETTE.

4.3 Second Series

The second series of simulations were conducted against the defender force mix of one infantry platoon and three tanks as shown in Table A-3 and Fig. A-2.

The attacker win-loss simulation results from analysis by Walker's model yielded the curves of Fig. A-8. The analysis considered "Z" as a function of attacker infantry, tanks, and the cross products of infantry and tanks. The artillery rate of fire, being held constant, was not considered as an independent variable. The resulting value is

$$Z = -5.1204 + 1.1402I + 0.4660T - 0.0563IT$$

where I = number of attacker infantry platoons, and
T = number of attacker tanks. in Walker's Model

$$P_S = (1 + e^{-Z})^{-1}$$

The probability of attacker success against the defender force mix of one platoon and three tanks shows that a smaller attacker force was required than against the 2 platoons — 2 tanks defender. Thus the simulations showed, quite reasonably, that a greater defender force required a stronger attacker force for similar attacker success.

To give some degree of credence to the curves of Fig. A-8, the chi-square goodness of fit test was applied to the data. The resulting chi-square value of 14.373 with 33 degrees of freedom, indicated that the data are very likely ($P = 0.95$) to occur from the curves of Fig. A-8. That is, in no case can expected results from Walker's model be rejected.

4.4 Third Series

Since the second series of defender force simulations had involved a weaker defender than the initial defender series, the defender force mix was strengthened for the third series.

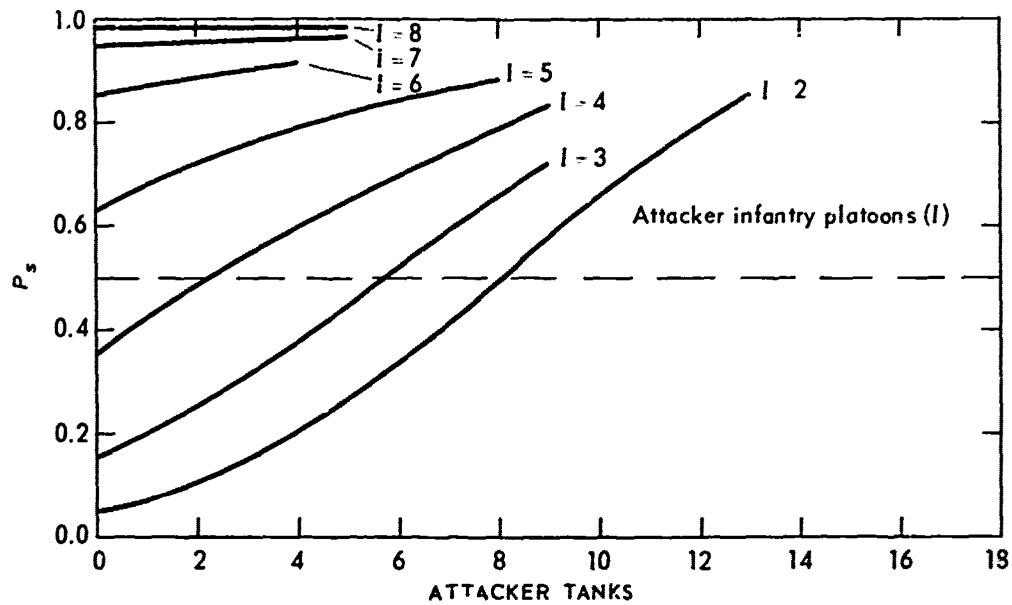

Fig. A8—Attacker Probability of Success Curves, 1 Platoon–3 Tank Defender
Arty rate of fire = 1.11 rds/min.

The third series of simulations were conducted against a defender force mix comprised of 3 infantry platoons and 1 tank. The infrequent (random) attacker wins of the higher attacker infantry strengths (7-9 platoons) precluded an analysis similar to that used previously. However, simulations of the attacker infantry strengths of 5 and 6 platoons did yield win-loss results when the 5 or 6 infantry platoons were combined with very large numbers of tanks (14-17) but the resulting attacker wins are substantially less than 0.50, (see Table A-7).

Unfortunately, limitations imposed by CARMONETTE did not permit simulations of such numbers of tanks combined with 7-9 infantry platoons (for the attacker force mix). Therefore the defender force mix of 3 infantry platoons and 1 tank was considered to be of sufficient strength to defend the area against a much stronger attacker than is permitted within the limitations of the simulation.

4.5 Fourth Series

Based on the results of the third series of simulations, the fourth series of simulations were conducted against a weaker defender force mix of 2 platoons of infantry and 3 tanks (i.e., initial defender plus one tank). An initial sample of 188 simulations was conducted. The results in terms of attacker wins are given in Table A-9 for the attacker force mixes simulated. The irrational win-loss outcomes of the simulations for specific attacker infantry strengths is obvious from Table A-9. For example, consider the occurrence of 6 attacker wins in 7 simulations involving the attacker force mix of 7 platoons and 5 tanks. In other attacker force mixes of 7 platoons investigated, at most 2 wins occurred from 6 battles. There is a trend throughout the higher infantry strengths for the occurrence of a lower number of attacker wins when the attacker force is strengthened by additional tanks.

These data, when analyzed by Walker's model, produced irrational results. The trend pointed out as indicating fewer attacker wins as the attacker force was strengthened was displayed by Walker's model for attacker force mixes of 8 and 9 infantry platoons. An almost constant attacker success probability for 7 infantry platoons regardless of the number of tanks deployed by the attacker (with the exception noted) was displayed. The model also displayed the general increase in attacker success as additional tanks were employed with 5 or 6 infantry platoons comprising the attacker force mix.

Table A-9

INITIAL SAMPLE OF ATTACKER WINS VS NO. OF REPLICATIONS
(2 Platoon — 3 Tank Defender)

Attacker tanks	Attacker Infantry Platoons				
	5	6	7	8	9
0				4/6	5/7
1				3/6	3/6
2			2/6	4/6	3/6
3			2/6	5/6	4/6
4			2/6	2/6	3/6
5			6/7		
6		3/6	1/6		
7		2/6	2/6		
8		2/6	2/6		
9		3/6			
10	3/6	4/6			
11	5/6	4/6			
12	3/6				
13	4/6				
14	3/6				
15	5/6				
16	6/6				
17	5/6				

In an attempt to obtain more meaningful results for the simulations involving the 2 platoons — 3 tank defenders, an additional 88 simulations were conducted. These simulations were conducted to increase the number of replications of combinations already investigated and to extend the range of attacker tanks within infantry strengths already investigated. The results are given in Table A-10 for attacker wins relative to the simulations conducted. No trends nor general indications were detected in these 88 simulations. The outcomes of the initial simulations and the additional simulations were combined (as given in Table A-7).

Table A-10

ADDITIONAL SAMPLE OF 88 ATTACKER WINS
VS NO. OF REPLICATIONS
(2 Platoon — 3 Tank Defender)

Attacker tanks	Attacker Infantry Platoons			
	6	7	8	9
2	2/6	--	--	2/4
3	--	--	--	--
4	1/6	--	2/4	3/4
5	--	--	--	--
6	--	3/4	3/6	3/6
7	--	2/4	--	--
8	1/4	3/4	2/6	--
9	1/4	4/6	4/6	--
10	0/4	--	--	--
11	0/4	2/6	--	--

When analysis by Walker's model was conducted, the initial trends became more pronounced. The family of curves derived by Walker's model was completely incomprehensible and irrational.* Because of this, the resulting family of curves is not given. The additional sample of 88 simulations, showing no inherent trends, did not obscure the trends already developed.

To test the behavior of the simulation outcomes for significance, the null-hypothesis that the probability of success equals 0.5 for all attacker mixes considered was assumed and the aforementioned chi-square goodness

*Subsequent work under another contract on this point, produced results that were in line with the other cases and confirms the belief that the results reported here were due to statistical fluctuations in the small sample.

of fit test,

$$\chi^2 = \sum_{i=1}^{k} \frac{(\text{observed}_i - \text{expected}_i)^2}{\text{expected}_i}$$

was employed.

Table A-11 gives the results of this test and the probability that the observed sample for various attacker infantry levels are statistically the same as $P_s = 0.50$. Although the results indicate that the outcomes of simulations conducted with the 5 infantry platoons and 10 to 17 tanks are less likely if we assume that $P_s = 0.50$ (i.e., a sample such as the results of the five infantry platoons would occur only 30-50% of the time if $P_s = 0.50$ whereas one may expect an outcome as occurred for 9 infantry platoons as often as 90-95% of the time when $P_s = 0.50$). However, in no case can we reject the hypothesis $P_s = 0.5$

Table A-11

RESULTS OF STATISTICAL TESTING FOR 275 SIMULATIONS
(2 Platoon — 3 Tank Defender)

Attacker infantry platoons	Combinations of tanks	Chi-Square calculated	Probability of occurrence when $P_s = 0.5$
5	10-17	7.33	.3 - .5
6	2-11	2.99	.8 - .9
7	2-11	3.84	.7 - .8
8	0-9	2.87	.8 - .9
9	0-6	1.18	.90 - .95

At this point it became pertinent to investigate the statistical confidence bounds surrounding these data results. Because of the lack of complete statistical analysis (noticeably establishment of confidence limits) for Walker's model, another measure of effectiveness was considered. The measure was developed directly for each simulation from the casualties suffered by the attacker and by the defender and denoted as:

$$V_R = \frac{C_B}{K_B} - \frac{C_R}{K_R}$$

where C_B = casualties of defender

C_R = casualties of attacker

K_B = casualty level for attacker win

K_R = casualty level for defender win

Reflection on the definition of V_R indicates that for defender wins V_R is negative, for attacker wins V_R is positive, and that V_R varies between -1 and +1, excluding zero (which indicates a draw). V_R may be interpreted as indicating the extent of attacker win or loss by the absolute magnitude of the value. A multiple regression analysis of the variable, V_R, was conducted for the defender force mix of 2 platoons and 3 tanks.

The multipie regression analysis yielded infantry families of curves strikingly similar to those derived by Walker's model. Further study of the two methods of analysis indicated a high correlation of the dependent variables (V_R and P_s). Such high correlation is to be expected since the two values are both defined on the basis of casualties of the attacker and defender.

Unlike Walker's model, methodology to establish statistical confidence bounds is available in multiple regression analysis. Figure A-9 gives the multiple regression results of the variable V_R and shows the 95% confidence regions of several curves. Especially noteworthy in Fig. A-9 is the large general area of overlap of the confidence regions of the expected value of V_R. (Such an overlap infers that an observed sample, as given, cannot be distinguished relative to that independent variable).

As a comparison with Fig. A-9 a multiple regression analysis with subsequent establishment of confidence regions was conducted for the V_R resulting from those simulations involving the defender force mix of one infantry platoon and three tanks. Figure A-10 gives the resulting curves from the multiple regression analysis and 95% confidence regions of these data.

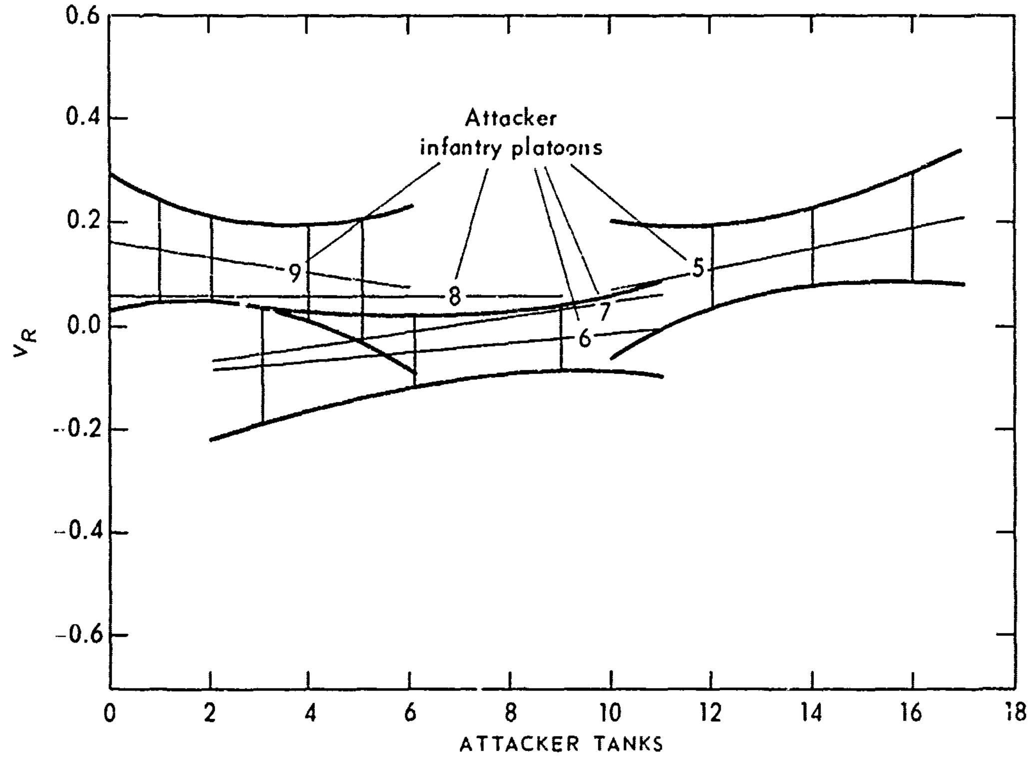

Fig. A9—Overlapping 95% Confidence Regions of Multiple Regression Analysis of V_R from Defender, 2 Platoon–3 Tank Simulations

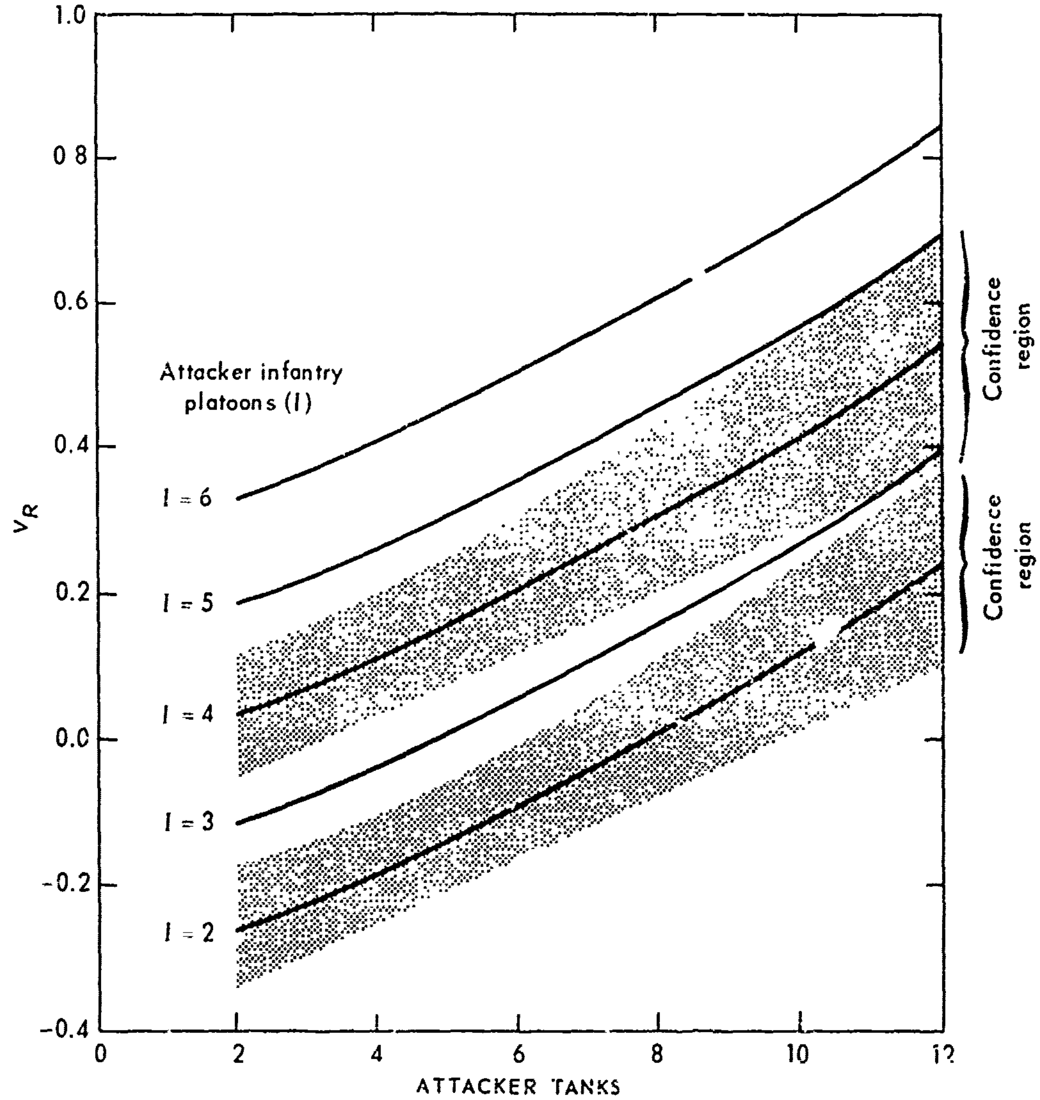

Fig. A-10—95% Confidence Regions of Multiple Regression Analysis of V_R from Defender, 1 Platoon–3 Tank Simulations

Consider now $V_R = 0$ on the ordinate of Figs. A-9 and A-10 and the 95% confidence limits of specific infantry curves. The point $V_R = 0$ is chosen because of its similarity to $P_s = 0.5$. Table A-12 lists the limits in terms of numbers of tanks for $V_R = 0$ in regard to the confidence regions shown.

Table A-12

RANGE OF TANKS PRODUCING $V_R = 0$
FROM 95% CONFIDENCE BOUNDS

Case	Defender		Attacker	Limits on Attacker Tanks for $V_R = 0$	
	Inf Plat	Tanks	Inf	Lower	Upper
1	2	3	3	5.2	9.6
2	2	3	5	5.0	11.3
3	2	3	7	0	6.2
4	2	3	9	4.5	10.8
5	1	3	2	6.1	9.7
6	1	3	4	0	3.2

Of interest in Table A-12 is the overlap of the limits of attacker tanks exhibited in the first four cases for $V_R = 0$. The limits on attacker tanks in cases 5 and 6 are in fact exclusive (show no overlap).

For a further investigation of the presumed statistical fluctuations occurring in the final outcomes of the simulations of the defender force mix of 2 infantry platoons and 3 tanks, an analysis was made of the casualties caused by the different weapon types in the simulations.* Simulations of two defender force mixes were considered, the 2 platoon — 3 tanks force mix and 2 platoon — 2 tank force mix. Table A-13 gives the average percentage casualties caused by the several weapon types in the simulations for each defender force mix. [illegible]sualties caused by the weapons types of the defender indicate the si[illegible]arity of the two series of simulations (one series involving a defender for a mix of two platoons and three tanks, and the other involving 2 platoons and 2 tanks) and further supports the belief that the overall outcomes of the 2 platoon — 3 tanks simulations are not the result of some anamolous behavior in the details of the minute-to-minute progress in the simulation.

*See footnote on page A-35

Table A-13

PERCENT OF CASUALTIES RESULTING FROM THE WEAPON TYPES
IN THE SIMULATIONS FOR TWO DEFENDER FORCE MIXES

Defender force mix		Casualties from defender wpns, %				Casualties from attacker wpns, %			
2 inf plats — 3 tanks		Mtr arty	Tank	AT	Small arms	Mtr arty	Tank	AT	Small arms
Attacker mix									
Inf plats	Tanks								
5	10-17	41	22	23	14	46	41	3	10
6	7-11	38	23	19	20	56	22	6	15
7	2-11	38	20	19	23	54	15	12	19
8	0-9	37	20	18	25	53	11	11	25
9	0-9	38	18	18	26	56	9	13	31
Defender force mix									
2 inf plats — 2 tanks									
Attacker mix									
Inf plats	Tanks								
4	8-16	39	18	24	20	48	40	3	9
5	5-14	37	21	22	20	58	26	4	12
6	6-13	37	18	19	25	55	23	6	16
7	0-7	37	15	13	36	61	5	11	23
8	0-5	38	14	12	35	68	3	4	25

The relatively small differences in percentages indicate the similarity of the two series of simulations. The median value for each weapon arm is shown in Table A-14 to emphasize the similarity of the two series.

Table A-14

MEDIAN CASUALTIES FROM THE WEAPON TYPES FOR TWO DEFENDER FORCE MIXES

Defender force mix	Casualties from defender wpns, %			
	Mtr arty	Tank	AT	Small arms
2 platoons — 2 tanks	37	18	19	25
2 platoons — 3 tanks	38	20	19	23
	Casualties from attacker wpns, %			
2 platoons — 2 tanks	58	23	6	16
2 platoons — 3 tanks	54	15	11	19

Although only small differences exist between the two defender series of simulations relative to the casualty producing weapons, certain trends are indicated in Table A-13. When the attacker force mix is strong in tanks, the resulting casualties from attacker tanks are heavy. Also, when attacker infantry is increased, the casualties from attacker small arms are increased.

The effect of the additional tank in the defender force mix is shown in Table A-13. In the simulations of the 2 platoon — 2 tank defender force, from 14-21% of the attacker casualties resulted from the defender tanks; whereas in the simulations with an additional defender tank, 18-23% of the attacker casualties were a result of defender tanks. The effect of the one additional tank in the defender force mix is graphically presented in Figs. A-11 and A-12 relative to tank deaths in the attacker force mix. The total attacker tank deaths show only small differences relative to the different defender forces. However a significantly larger percentage of attacker tanks were killed by the three defender tanks than by the two defender tank force mix.

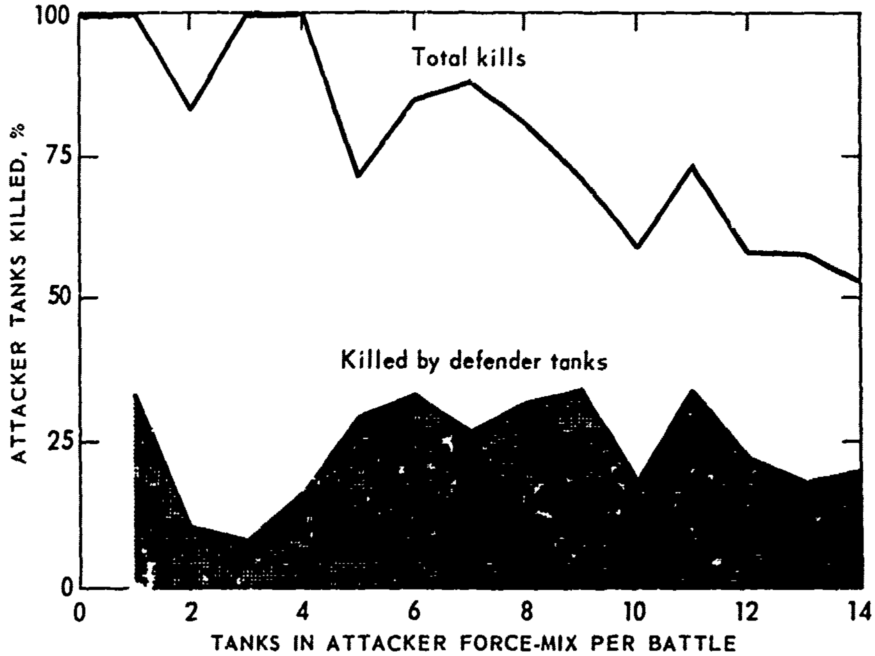

Fig. A11—Attacker Tank Deaths in Defender 2 Inf Plt–2 Tank Battles

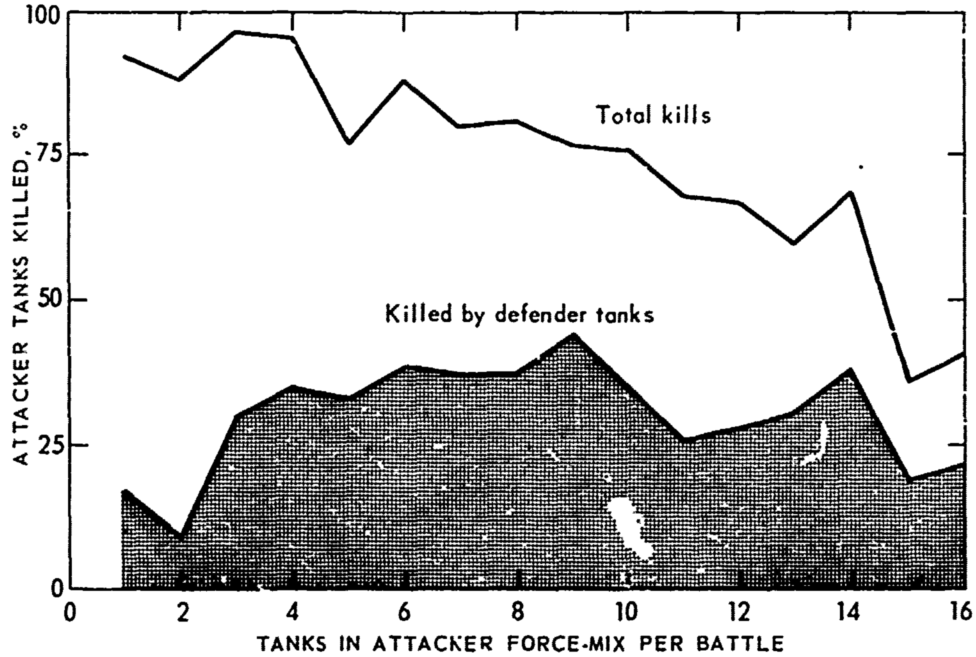

Fig. A12—Attacker Tank Deaths in Defender 2 Inf Plt–3 Tank Battles

Nevertheless, the final outcomes of the simulations conducted with a defender force mix of 2 infantry platoons and 3 tanks do not provide useful data (see Table A-7, the last section).* However, this does not mean that the previous analyses (Figs. A-5 — A-8) are not useful. The statistical validity of these results (Figs. A-5 — A-8) has been demonstrated (Table A-8). Also, the rational behavior of weapon types relative to casualty production for both the defender and attacker emphasize the validity of the simulation.

4.6 Trade-Offs

From the curves given in Figs. A-5, A-6, A-7, and A-8, attacker infantry tank trade-off values can be developed for constant effectiveness. The constant effectiveness selected for this determination is 0.5. Figure A-13 gives the isoeffectiveness curves of the 2 platoon — 2 tank defender force for each artillery rate of fire and also the curve for the defender force mix of 1 platoon infantry and 3 tanks. The simulations of defender force mix of 3 platoons and 1 tank resulted in attacker success which was much less than 0.5 in all cases. Therefore no isoeffectiveness curve is presented since a gross extrapolation of these data would be necessary. No curve of isoeffectiveness is presented for the defender force mix of 2 infantry platoons and 3 tanks because of the previously described outcomes.

Table A-15 gives the number of tanks required by the attacker with a specific infantry strength to produce a constant effectiveness of 0.5.

The data of Table A-15 are roughly, linear. Therefore, the trade-offs between infantry and tanks are approximately linear. The linear correlation coefficients between tanks and infantry for the four categories of data in Table A-15 are from .98 to .99. If the variates, tanks, and infantry were independent of each other, a correlation coefficient of zero or close to zero may be expected. The high correlation exhibited in regard to linearity rejects their independence. The infantry-tank trade-offs derived by linear regression are given in Table A-16.

*See footnote on page A-35

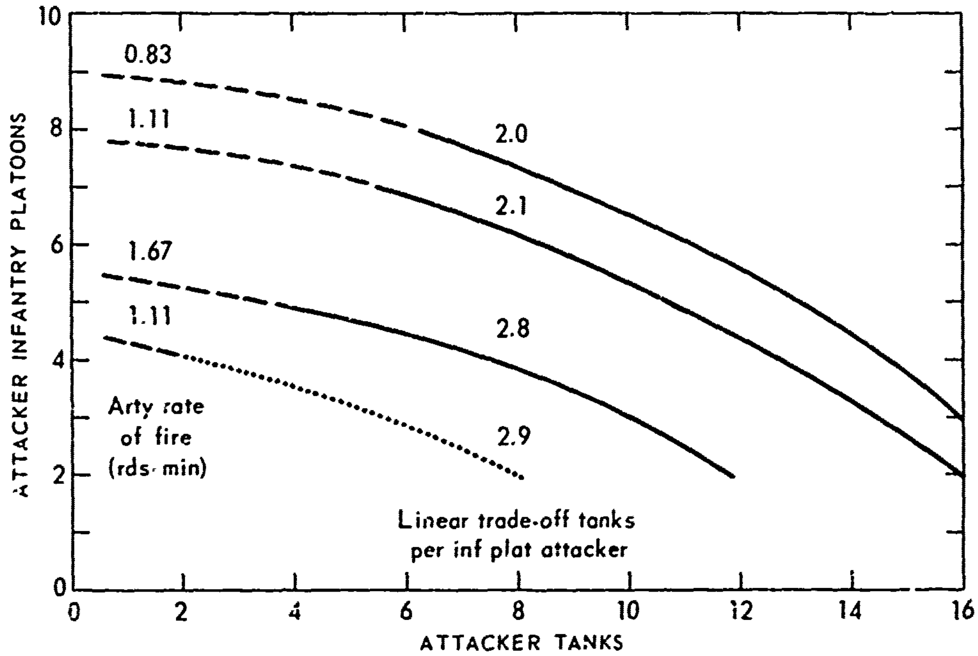

Fig. A-13—Trade-Off Curves Resulting from CARMONETTE Simulations of 2 Platoons and 2 Tanks Defender and 1 Platoon–3 Tanks Defender

Defender Force-Mix: ——— 2 platoons–2 tanks ·········· 1 platoon–3 tanks

Table A-15

NUMBER OF TANKS REQUIRED BY THE ATTACKER WITH SPECIFIC INFANTRY STRENGTH FOR ISOEFFECTIVENESS**

Attacker infantry platoons	Defender force mix (inf plats — tanks)			
	(2-2)	(2-2)	(2-2)	(1-3)
	Artillery rate of fire			
	0.83 rds/min	1.11 rds/min	1.67 rds/min	1.11 rds/min
2	(17)*	15.9	11.8	8.0
3	15.9	14.4	10.0	5.7
4	14.7	12.7	7.6	2.3
5	13.2	10.7	3.6	--
6	11.2	8.5	--	--
7	9.0	5.5	--	--
8	6.2	(0)	--	--
9	(0)	--	--	--

*Parenthesis are extrapolated values.

**Probability of success = 0.50.

Table A-16

TRADE-OFFS OF ATTACKER TANKS AND INFANTRY (FOR DIFFERENT ARTILLERY RATES OF FIRE AND DEFENDER FORCE MIXES)

Defender force mix infantry platoons	tanks	Artillery rate of fire (rds/min)	Attacker tanks per infantry platoon
2	2	0.83	2.0
2	2	1.11	2.1
2	2	1.67	2.8
1	3	1.11	2.9

4.7 Derived Firepower Score of Attacker Tanks

In order to illustrate the methodology and tentative results of this study in terms of improving the firepower score for a tank, the firepower score of an attacker tank are calculated here with several alternative considerations given to artillery effectiveness. The approximately linear trade-offs, given in Table A-16, were considered for the range of attacker infantry strengths applicable. Subsequently firepower scores for attacker tanks could be calculated.

Firepower measures, as given in the TBM documentation, were combined to calculate the scores of the attacker infantry platoons. Commensurate fire from infantry support weapons (as given in Table A-5) were evaluated as well as the number of infantry platoons in the calculations. Consideration was given to the effectiveness of the attacker artillery as the levels of infantry strength were decreased (from 9 platoons to 8 platoons, to 7 platoons, etc.). Previous analysis (Tables A-13 and A-14) of the various percentages of casualties caused by the weapon types indicated that, when attacker infantry strength decreased from 8 to 4 platoons, artillery-caused casualties decreased about 20 percent. Thus a 5 percent degradation of artillery effectiveness was considered to be roughly equivalent to the decrease of the attacker infantry strength by one platoon. Therefore, artillery firepower scores were degraded a uniform 5 percent per infantry platoon as infantry strength was decreased for results as shown in Table A-17.

Secondly, artillery effectiveness was proportionally decreased relative to the decreasing attacker infantry platoon strength. That is, as infantry platoons decreased by one platoon, a loss of one-ninth (1/9) artillery effectiveness was assumed; for example for the six infantry platoon attacker force, a reduction of 33 percent of the total artillery firepower resulted. The results of proportionate sharing of artillery is given in the second section of Table A-17.

In the third treatment, artillery effectiveness was considered to be constant. No degradation factor was assumed for lower infantry platoon strength. The firepower effectiveness of the artillery for attacker infantry strength of 2 platoons is equal to that of 9 platoons. The resulting derived firepower scores for a tank based on constant artillery are given in the third section of Table A-17.

Lastly, artillery effectiveness was excluded in the computation of the infantry firepower score. Obviously, the exclusion of the artillery had a large effect in decreasing the average firepower score per infantry platoon, and consequently decreasing the derived firepower score per tank. This treatment is presented in the last section of Table A-17.

5. NEED FOR FUTURE RESEARCH

Although some effort has been expended on the establishment of statistical confidence of the results in the present study, statistical confidence limits on the trade-offs of infantry and armor should be investigated further.

The effects of possible combinations of factors such as terrain, type of engagement and weapon characteristics have not been investigated here. Future work should investigate the effects of some of the combinations of these variables. An extension of the relative effects of a greater variety of defender force mixes should also be considered.

Table A-17

DERIVED FIREPOWER SCORE OF ATTACKER TANKS

Defender inf plats	Defender tanks	Artillery rds/min	Attacker inf plats	Linear trade-off (Attacker tanks per inf plat)	Average firepower score per inf plat	Derived firepower score of tank
5% Degradation Factor on Artillery						
2	2	0.83	3-8	2.0	2.489	1.24
2	2	1.11	2-7	2.1	2.752	1.31
2	2	1.67	2-5	2.8	3.169	1.13
1	3	1.11	2-4	2.9	3.630	1.25
With Proportionate Share of Artillery						
2	2	0.83	3-8	2.0	2.025	1.01
2	2	1.11	2-7	2.1	2.025	0.96
2	2	1.67	2-5	2.8	2.025	0.72
1	3	1.11	2-4	2.9	2.025	0.70
With Constant Firepower of Artillery						
2	2	0.83	3-8	2.0	2.863	1.43
2	2	1.11	2-7	2.1	3.339	1.59
2	2	1.67	2-5	2.8	4.092	1.46
1	3	1.11	2-4	2.9	4.639	1.60
Excluding Artillery						
2	2	0.83	3-8	2.0	0.720	0.36
2	2	1.11	2-7	2.1	0.720	0.34
2	2	1.67	2-5	2.8	0.720	0.26
1	3	1.11	2-4	2.9	0.720	0.25

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Appendix B

CASUALTY RATES AS A FUNCTION OF FORCE RATIO

Appendix B

CASUALTY RATES AS A FUNCTION OF FORCE RATIO

1. INTRODUCTION

1.1 Purpose

The purpose of this study was "to develop average casualty rates, as a function of force ratio, for use in war game models of modern, nonnuclear war, based upon loss experience in World War II and the Korean War." Data on strengths and casualties for American units in a variety of engagements, already compiled by the Historical Evaluation and Research Organization (HERO),* was to be compared with similar data to be obtained on enemy strengths and casualties, analyzed, and presented in a form that would be useful as input for the design of the TBM-68 family of war games.

1.2 Enemy Records

Enemy records now available in the United States rarely include data for units below division level, and those for US combat elements available for this study were limited in quality and level of resolution by the purpose for which they were originally compiled. As a result, it has been impossible in this study to provide calculations for organizations smaller than divisions, except in those few instances where individual regiments were independently engaged for limited periods. More highly detailed figures could probably be acquired by thorough investigation of the records of US units down through battalions to the extent that such records are still available. Should it be determined that low-echelon records are no longer available in adequate quantities, it is believed that useful approximations for regimental, battalion, and company losses can be derived from division records by an extension of methodologies developed during the course of this study.

Because of the nature of warfare as well as the nature of the records, it has proved impossible to provide meaningful figures on an hourly basis. Some information is available on the intensity and duration of combat on certain days, but it is no more possible to ascertain the distribution of casualties by category or time than it is valid to assume that they were spread evenly over the duration of the combat.

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*Data compiled in connection with HERO's study, under subcontract to RAC, "Historical Analysis of Wartime Replacement Requirements; Experience for Selected Major Items of Combat Equipment."

1.3 Time Resolution

The actions considered in this study occurred under widely varying conditions of terrain and climate, the former ranging from broad treeless plains to rugged and almost impenetrable mountains, the latter from the temperate climate of Northwest Europe to the semitropical monsoon climate of Okinawa. While it is most certainly true that the nature of the terrain was significant in many instances, and particularly when it was rugged, as in Okinawa and Italy, it has not proved practical from available data to isolate cases for study on the basis of a certain type of terrain, or to identify a type as "average." Rather it has been assumed that the variety of terrain represented in the several actions herein presented, by ranging from one extreme to the other, in fact produces a gamut of types that will yield a more accurate representation of actual combat conditions than would restriction to a single type, be it the one which most significantly affected combat or that which had the least influence on its development.

1.4 Volume of Fire

Fairly early in the analysis it became clear that in modern warfare force ratios are dependent not only on firepower capabilities, but to an even greater extent upon volume of fire actually delivered in a combat situation. In the time available for this study, it would be impossible to estimate what these volumes were in the various engagements analyzed without exhaustive research of logistical records, shell reports, situation reports, and the like.* Thus the force ratios shown in this study, based upon strength and firepower scores are to some extent distorted. Offsetting this, however, is the fact that the relative capabilities of different opposing national forces to some extent provided an inherent reflection of the respective logistical capabilities of the opposing forces. In any event, the conclusions of the report suggest that allowances can and should be made for this factor in future casualty assessments.

1.5 Qualitative Influences

While historical and military judgment have been applied in the interpretation of the records, no effort has been made in this study to evaluate the various qualitative influences on the data derived and presented. It is

*One possible exception is Anzio, where it has been estimated that the volume of American artillery fire was between 13 and 20 times as great as that of German fire. But, since the Germans were clearly more selective in choice of targets, this does not mean that US artillery fire was 13 times as effective.

important, however, that these influences not be ignored in the development of realistic combat models — such influences, for example, as leadership, doctrine, morale, and logistical support. To some extent it is believed that these factors and considerations have cancelled themselves out in the development of the average figures in the report. The extent to which they have done so is open to some question, however. Not only for analytical purposes, but for the purpose of improved war gaming, it is important to attempt to evaluate in some fashion the influence of such factors on the outcome of combat.

2. METHODOLOGY

Since HERO was not aware of any similar study of comparable scope ever having been undertaken, a large proportion of the time allotted to this study had to be spent in evolving a methodology both for obtaining source material and for most effectively analyzing it.

2.1 Available US Records

As was indicated in the original study proposal, extensive figures on strengths and casualties of US forces were already available at HERO. These pertained to:

The 45th Division in Italy and Northwest Europe
The 28th Division in Northwest Europe
The 2d and 25th Divisions in Korea
The 7th and 96th Divisions on Okinawa.

2.2 Enemy Records

It was necessary, therefore, to procure similar information for the enemy units which these US forces opposed, first identifying those units from intelligence reports, enemy records, historical narratives of units, and other similar sources.

No Japanese, North Korean, or Chinese Communist records are available. Consequently figures on casualties and strengths of those forces were procured entirely from the reports of the opposing US units, and must be viewed with considerable caution. Following World War II

the major portions of the official records of the German Army were brought to Washington. They were retained in what is now the Federal Records Center for several years and available for research to historians and others. It was finally decided, however, that the records should be returned to the German government. Before their release, many of the documents were microfilmed and the microfilm stored in the National Archives. Unfortunately for the purposes of this study, no one foresaw the usefulness of the personnel records included in this material, and virtually none of them was microfilmed. It happened, however, that some documents reporting strengths and casualties were included in appendix material and otherwise enclosed with microfilmed records of operations, intelligence, etc. It is from these that the information used in this study was obtained. Unfortunately, there was no way of predicting where such material would be found within the microfilmed records. Hence a great deal of time was spent fruitlessly looking through records of units known to have opposed the US forces under survey. After about 200 hours of searching microfilm (140 rolls, representing 15 units), it became necessary to abandon consideration of the 28th Division in northwest Europe (August to December 1944), since no pertinent German casualty figures were available. Because of a chance discovery of information on two other German divisions (16th Infantry and 21st Panzer) during the Lorraine Campaign (September 1944), it was decided to search out figures for the US 79th Division, which opposed those divisions at that time, but which had not been included in the earlier study. Hence the 79th Division and its combat with these two German divisions has been added to the original list. For lack of information on German units, the action of the 45th Division in northwest Europe also had to be dropped. Also omitted from the study as originally envisaged was the 2d Division in Korea, because time did not suffice to search out the records.

2.3 Types of Statistical Material

The statistical material on US forces was adequate, but some of it, having been gathered for a study with a different objective, was not fully adaptable to the requirements of this one. With more time for review of primary sources this problem could probably be eliminated. One serious instance of conflicting and contradictory records for an American division was found, raising some doubts as to the reliability of other records for that division.

Although there was in no case as much information available on German strengths and casualties as would have been desirable, that which was used was deemed adequate for the purposes of this brief study, and certainly for proving the validity of the methodology employed. US records contain day-by-day reports of strengths and casualties at the division level for virtually all units engaged in Europe, and at least some lower echelon reports are also available. In only a few instances were daily reports of German strengths and losses found, and these covered isolated periods of a few days. Much of the material was in the form of monthly reports at the corps or army level. In some cases information pertaining to the same period was found in different forms, although frequently conflicting, necessitating evaluation, and application of professional judgment.

While limitation of time and funds precluded going beyond data already available, save for the 79th Division as indicated above, the feasibility of another and more rewarding approach to the problem addressed by this study was clearly indicated. This approach would, in effect, reverse that employed here. First, the availability of detailed records of German units under various combat postures would be determined from West German sources, and microfilm or other copies of these obtained. Then records of opposed US units would be researched and data compiled for comparison at the lowest possible levels of resolution.

Information on enemy strengths and losses in North Korea and Okinawa came from US intelligence reports, based primarily on interrogations of prisoners and identification of enemy dead. These reports were normally made on a daily basis and are readily available.

2.4 Interpretation and Use of the Material

Manpower strengths for each unit in each engagement were derived directly from documentary sources, with additional assistance from historical sources, and particularly the series of volumes on the History of World War II prepared by the Office of the Chief of Military History. In the calculations and analyses made of the data the average unit strength during the engagement was normally used. When daily strengths were not available, figures representing the strength at each end of the period, normally a month, were usually at hand, and from these an average daily figure was derived.

Casualty figures were available in various forms. For purposes of this study casualties were interpreted as including Killed in Action, Wounded in Action, Missing, Captured, Prisoner of War, and any variation of these.

In cases where the only German casualty figures available were those accumulated for a stated period, usually ten days or one month (16th Panzer Division at Salerno, 16th Infantry Division and 21st Panzer Division in Lorraine), a daily breakdown of casualties was estimated, based upon knowledge of the situation existing, the nature of the combat in which the units were engaged throughout the period, the intensity of the combat indicated by casualty figures of US forces, knowledge of the course of operations, and experience with similar forces in similar situations.

Enemy strength figures also were not always as complete as desired, and sometimes were available only on a month's-end basis. Again, casualty figures and outside information as to the units engaged and the type of action made it possible to estimate with considerable confidence the average strengths of the forces engaged.

Japanese casualty figures on Okinawa, derived solely from US sources, include only killed, broken down into several categories, including estimated dead as well as counted dead and estimated numbers sealed in caves. While every Japanese soldier on the island ultimately became a casualty, the accuracy of these daily figures is impossible to validate. There are no figures at all on Japanese wounded. On the assumption that Japanese wounded were 3-4 times as great as their killed, but bearing in mind the Japanese practice of holding positions at all costs until all — including previously wounded — were dead, while at the same time recognizing that numbers of wounded must have been evacuated during the kind of combat which took place on Okinawa, it was found that doubling the number of counted dead, while ignoring other estimated categories, gave the most plausible total for dead and wounded.

For Korea, two sets of estimates of enemy casualties are available in US records: those of the engaged US unit, in its daily reports, and subsequent estimates of Far East Command, based upon examination, analysis, and correlation of all casualty reports received. It is believed that these FEC estimates were, in turn, correlated with reasonably accurate intelligence of initial strengths of major enemy units, and of the replacements which reached them from China and North Korea.

Accordingly, we have accepted the FEC figures, as providing a reasonable estimate of all enemy casualties. These evidently do include prisoners of war. It is not certain whether they include estimates of wounded. We have assumed they do, since the application of any standard relationship of killed to wounded, ranging from 1:1 to 1:3, would result in an overall casualty total that we believe would be unrealistically high. We think, however, that this question of enemy casualties should be investigated more thoroughly than was possible in the time available for this study.

2.5 Organization and Analysis of Data

2.5.1 The Calculation of Force Ratios. Calculation of manpower strength on each side in each engagement was based upon figures obtained from contemporary records, adjusted in accordance with reports of specific units engaged at a given time. Thus when, in the first day at Salerno, it was known that only two of the three regiments of the 45th Division had landed, the strength of two regiments rather than three, and without the availability of most division support units (other than artillery) was assumed. Again, when the German 16th Panzer Division was conducting a delaying action between September 17 and 25, it was assumed that only half of the division would have remained in contact with the 45th US Division, since approximately half of the entire German force was presumably engaged in preparing for defensive action north of Naples.

For more effective use in war gaming, RAC requested that the calculations of this study be based not upon manpower strength alone, but upon manpower plus weapons. This would have been necessary in any case. While some data for determining the relative firepower of weapons is presented in USCONARC Pamphlet, "War Gaming Handbook,"[1] we do not have available any indication of how these data are applied to a range of specific weapons, or of the validity of the resulting relationships. The RAC study of firepower scores for the TBM-68 would not be completed in time to be used here. In an earlier study, "Historical Trends Related to Weapon Lethality,"[2] HERO developed a relatively simple method of calculating the relative firepower or lethality of all weapons, ranging from the sword to the atomic bomb. The theoretical results appear to relate validly to each other, although they do not reflect the effects of terrain or other frequently unquantifiable circumstances of combat. Recognizing this shortcoming, HERO has used the method in this study to develop fully comparable figures for relative lethality, or firepower of weapons, since nothing else as reliable is available.

2.5.2 Calculation of Weapon Lethality. With this method, calculation of the inherent lethality of a weapon involves the following elements: (1) rate of fire in effective strikes per hour under ideal conditions; (2) number of potential targets per strike, assuming the target to consist of men in massed formation; (3) relative incapacitating effect of each strike; (4) effective range; (5) accuracy; and (6) reliability. In the case of tanks and other mobile weapons systems mobility and vulnerability are also considered. Multiplication of the factors representing each of these elements for any given weapon results in a figure which represents the relative lethality of the weapon. (A fuller discussion of this method is included in unpublished notes available at RAC.)

The lethality index of the weapons employed in the actions considered in this study has been calculated by this method (see App G, unpublished notes, available at RAC). Table B1 gives the indexes of lethality for representative weapons of the WWII era. Using Tables of Equipment (TOE) or other sources for numbers of each type of weapon authorized for or actually employed by the units involved, the total firepower — in terms of lethality indexes — for each of the forces has been calculated. The ratio of these totals and the ratio of manpower strengths have been multiplied to give a force ratio product for the attacker and defender in each action. The square root of this quantity is the geometric mean and is the measure of effectiveness used in the calculation of the force ratio. (This is quite an arbitrary procedure, and it may be that further analysis will reveal that greater weight should be applied either to numerical strength — because of ground-covering or maneuvering capabilities — or to firepower capabilities; or that some other relationship should be developed.) The force ratio products have been plotted on the accompanying graphs against the casualties per day as a percent of strength. It must be stressed that this method of calculating firepower capabilities does not allow for substantial differences in logistical capabilities, or for doctrine in the employment of weapons or ammunition.

2.5.3 North Korean and Chinese Weapons. In the case of the North Koreans and the Communist Chinese, although knowledge of the weapons actually at hand is incomplete, there is information as to the usual number and variety of weapons authorized for various units. Since the weapons were a miscellaneous assortment from various nations, their firepower and the total firepower of the forces have been estimated on the basis of comparable weapons used by US or German forces. Additional research might make it possible to refine the figures further, but no significant modification could be anticipated without access to the records of the enemy

TABLE B-1

FIREPOWER SCORES OF WEAPONS USED BY

US INFANTRY DIVISION -1943

Carbine, cal .30	.59
Rifle, cal .30M1	1.00
Rifle, cal .30 M1903	.75
Pistol, auto, cal .45	.16
Rifle, BAR	2.32
Machinegun, cal .30 (hv)	6.45
Machinegun, cal .30 (lt)	3.09
Machinegun, cal .50	8.05
Submachinegun, cal .45	1.27
Gun, 57 mm (AT)	189.00
Howitzer, 105 mm	619.00
Howitzer, 155 mm	470.00
Launcher, rocket, 2.36 in.	83.10
Mortar, 60 mm	88.00
Mortar, 81 mm	235.00
Gun, 37 mm	49.20
Car, armored (37 mm gun and LMG cal .30)	291.00
Tank, medium	2,160.00
Tank, light	326.00

Source: Unpublished notes by HERO.

forces. This was true to a much less extent of the Japanese who, at Okinawa, still maintained a close to normal level of organization and equipment. The nature of the campaign, moreover, which resulted in capture of the entire island, made it possible for US forces to count and record the weapons that were left by the departed Japanese. Again, a more thorough study of the record than has been possible in the limited time for this study would probably produce some modification of the figures used in the calculation of force ratios.

<u>2.5.4 Effect of Personnel Strength.</u> The firepower of US units, as stated above, is based on authorized TOE. It has not been deemed necessary in most instances to vary the firepower figures for a unit to reflect manpower losses, or excess personnel over TOE. Thus a full division has always been considered at full TOE strength for weapon lethality firepower purposes. Similarly enemy units, except when only a portion is known to have participated in an action, or when they are known to have been short of major armament, are calculated at full strength. The basis for this is the assumption based on professional experience that a military unit will normally maintain its heavy and crew-served weapons in combat as long as possible and that reductions in personnel represent primarily losses in hand weapons (rifles or carbines), and these predominantly in noncombat assignments. Thus, until they become extensive, personnel shortages have relatively little effect on the total firepower figure for the unit.

3. THE ENGAGEMENTS

Listed below are the 37 engagements analyzed for this study:

<u>3.1 World War II — Italy</u>

1. Salerno, September 11, 1943 — Attack from the Beachhead. Attack by US 45th Division from the beachhead against hasty defense by the German 16th Panzer Division.

2. Salerno, September 12-14, 1943 — German Counterattack. German 16th Panzer Division counterattack against hasty defense by the US 45th Division.

3. Salerno, September 17-25, 1943 — Advance to Naples. Advance to Naples by US 45th Division against delaying action by German 16th Panzer Division.

4. Volturno, November 6-13, 1943 — Attack in the Mountains. Attack in mountains by US 45th Division against prepared positions of the German 26th Panzer Division.

5. Anzio, February 7-9, 1944 — Moletta River Defense. Initial hasty beachhead defense by elements of the US 45th Division against elements of the German 65th Infantry Division.

6. Anzio, February 11-12, 1944 — Aprilio Counterattack. Counterattack by US 45th Division against prepared defenses of the German 715th Infantry Division (reinforced).

7. Anzio, February 16-19, 1944 — German "Bowling Alley" Offensive. The major German offensive, German Combat Group Greiser (approximately three divisions) against prepared defenses of the US 45th Division.

8. Anzio, February 21-23, 1944 — German Beachhead Defense Line Offensive. Continued offensive by the German 114th Infantry Division (reinforced) against the US 45th Division.

9. Anzio, February 21-23, 1944 — Allied Beachhead Counterattack. US 45th Division counterattacks (as a part of overall Allied counterattack) against prepared positions of the German 114th Infantry Division. (Note — Engagements 8 and 9 are identical.)

3.2 World War II — France

10. Lorraine, September 13-16, 1944 — Advance to the Moselle River. Attacks by the US 79th Division against hasty defense by the German 16th Infantry Division.

11. Lorraine, September 19-23, 1944 — Advance to the Meurthe River. Attacks by the US 79th Division against delaying action by the German 21st Panzer Division.

3.3 World War II — Okinawa

12. Advance from the Beachhead, April 1-4, 1945. Advance of the US 96th Division against delaying action by the Japanese 1st Specially Established Regiment.

13. Machinato Offensive — I, April 5-12, 1945. Attack by the US 96th Division against Japanese 12th and 13th Battalions in fortified positions.

14. Machinato Offensive — II, April 19-23, 1945. Attack by the US 96th Division against the Japanese 62d Division in fortified positions.

15. Shuri Line Offensive, May 10-25, 1945. Attack by the US 96th Division against Japanese 24th Division in fortified positions.

16. Advance from the Shuri Line, May 31- June 5, 1945. Attacks by the US 96th Division against delaying action by the Japanese 24th Division.

17. Final Yuza Offensive, June 6-17, 1945. Attack by the US 96th Division against Japanese 24th Division in fortified positions.

18. Advance from the Beachhead, April 1-4, 1945. Advance by US 7th Division from beachhead against delaying action by Japanese 1st Specially Established Regiment.

19. Machinato Offensive — I, April 5-8, 1945. Attack by US 7th Division against Japanese 12th and 14th Independent Battalions in fortified positions.

20. Machinato Offensive — II, April 9-23, 1945. Attack by US 7th Division against Japanese 63d Brigade in fortified position.

21. Advance to the Shuri Line, April 24-May 3, 1945. Attack by US 7th Division against Japanese 24th Division in a delaying action.

22. Japanese Counterattack, May 4, 1945. Counterattack by Japanese 24th Division against US 7th Division in hastily prepared position.

23. Shuri Line Offensive, May 5-8, 1945. Attack by US 7th Division against Japanese 24th Division in fortified position.

24. Advance from the Shuri Line, May 22-30, 1945. Attack by US 7th Division against Japanese miscellaneous units in a delaying action.

25. Advance to the Escarpment Redoubt, May 31-June 8, 1945. Attack by US 7th Division from Shuri Line against Japanese 63d Brigade in a delaying action.

26. Final Escarpment Offensive, June 9-18, 1945. Attack by US 7th Division against Japanese 63d Brigade in fortified position.

3.4 Korean War

27. Pusan Perimeter Defense, September 16-18, 1950. Defense of prepared positions by the US 25th Division against attacks of the 6th and 7th North Korean Divisions.

28. Offensive from Pusan Perimeter, September 18-21, 1950. Attacks by the US 25th Division against withdrawal from hasty defense by the 6th and 7th North Korean Divisions.

29. Nam River Operation, September 22-24, 1950. Attack by the US 25th Division against delaying action of the 6th and 7th North Korean Divisions.

30. Pursuit through Kunson, September 25-30, 1950. Attacks by US 25th Division against 6th and 7th North Korean Divisions in withdrawal from hasty defense.

31. Crossing of the Han River, March 7-9, 1951. Attack by the US 25th Division against prepared defenses of the 38th and 50th Chinese Communist Forces Army.

32. Attack toward "Butte" Line, February 3-7, 1951. Attack by the US 25th Division against hasty defenses of the 50th Chinese Communist Forces Army and II North Korean Corps.

33. Attack toward the Chan River, April 3-5, 1951. Attack by the US 25th Division against hasty defenses of the 26th Chinese Communist Forces Army.

34. Withdrawal to "Kansas" Line, April 23-27, 1951. Delaying action by the US 25th Division against attacks by the 60th and 12th Chinese Communist Forces Army.

35. Attack toward Line "Pierce," May 20-23, 1951. Attack by the US 25th Division against hasty defenses by the 64th and 65th Chinese Communist Forces Army.

36. Iron Triangle Defense, Jun 1-2, 1951. Defense of hasty defense positions by the US 25th Division against attacks by the 63d Chinese Communist Forces Army.

37. Attack toward Line "Bayonet," June 3-5, 1951. Attack by the US 25th Division against prepared defenses of the 63d Chinese Communist Forces Army.

4. TABULAR PRESENTATION OF CASUALTY DATA

This presentation of the casualty data is intended to summarize, in tabular form (Table B2) all of the basic statistics compiled for each of the 37 engagements analyzed in the study.

The number of postures analyzed is as follows:

Attack	37
Defense of fortified positions	9
Defense of prepared position	8
Hasty defense	11
Delaying action	10
Withdrawal from action	4

A total of 42 defense postures are listed because, in five instances, two defensive postures are indicated for the following reasons:

a. Engagement No. 4, German defense in the mountains north of the Volturno River, was originally considered to be an example of defense of a prepared position. Because of the nature of the terrain, however, as well as the extremely well-prepared defenses, it is believed that this should also be considered as defense of a fortified position.

b. In Engagements 10, 28, 29, and 30, the defender had planned either a defense or a delaying action; the attacker's success, however, forced the defender in these engagements to attempt a withdrawal in action, since he was unable to accomplish his original mission.

The more successful side in each of these engagements is indicated by a circle drawn around the posture indicator.

Table B-2

CASUALTIES, POSTURES, AND FORCE RATIOS

Engagement	Date	No. of Days	Atk	Defender Posture: Fort Def	Defender Posture: Prep Def	Defender Posture: Hasty Def	Defender Posture: Delay	Attacker's Characteristics: Strength Manpower	Attacker's Characteristics: Relative Firepower	Atkr Cas/Day as % of Strength	Defender's Characteristics: Strength Manpower	Defender's Characteristics: Relative Firepower	Dfdr Cas/Day as % of Strength	Manpower Ratio	Firepower Ratio	Mean Force Ratio
WW II - Italy																
1. Salerno - I	9/11/43	1	x			x		8,388	472	2.990	7,325	162	1.368	1.145	2.901	1.82
2. Salerno - II	9/12-14/43	3	x			x		14,229	334	1.687	8,388	771	1.600	1.696	0.433	0.86
3. Salerno-III	9/17-25/43	9	x			x		15,576	284	0.276	6,702	169	0.239	2.324	1.684	1.98
4. Volturno	11/6-13/43	8	x		x			15,579	284	0.526	8,165	86	0.369	1.908	3.278	2.50
5. Anzio-I	2/7-9/44	3	x			x		7,312	58	1.531	5,310	86	0.602	1.377	0.674	0.96
6. Anzio-II	2/11-12/44	2	x		x			11,212	533	0.749	13,319	136	0.773	0.842	3.892	1.81
7. Anzio-III	2/16-19/44	4	x		x			26,421	601	2.126	15,797	728	2.171	1.674	0.826	1.18
8. Anzio-IV	2/21-23/44	3	x		x			15,265	148	1.092	15,807	257	1.381	0.966	0.575	0.74
9. Anzio-V	2/21-23/44	3	x		x			15,807	257	1.381	15,265	148	1.092	1.037	1.739	1.34
WW II - France																
10. Lorraine- I	9/13-16/44	4	x			x		13,758	159	0.554	4,219	9	15.696	3.261	16.163	7.26
11. Lorraine-II	9/19-23/44	5	x				x	13,386	150	0.843	5,632	63	0.916	2.377	2.362	2.38
WW II-Okinawa																
12. Okinawa-I	4/1-4/45	4	x				x	20,796	509	0.631	1,400	4	33.000	14.854	116.704	41.64
13. Okinawa-II	4/5-12/45	8	x	x				19,893	509	1.583	2,900	22	20.680	6.859	22.550	12.44
14. Okinawa-III	4/19-23/45	5	x	x				20,137	509	1.392	13,923	54	3.820	1.446	9.439	3.69

15. Okinawa-IV	5/10-25/45	16	x	x				21,734	539	1.049	16,430	70	3.604	1.323	7.642	3.18
16. Okinawa-V	5/31-6/5/45	6	x				x	20,911	539	0.289	8,250	35	3.899	2.523	15.284	6.21
17. Okinawa-VI	6/16-17/45	12	x	x				20,424	539	0.491	8,250	35	3.640	2.475	15.284	6.15
18. Okinawa-VII	4/1-4/45	4	x				x	20,510	489	0.545	1,400	4	13.714	14.650	111.641	40.44
19. Okinawa-VIII	4/5-8/45	4	x	x				19,860	489	0.532	2,900	22	18.276	6.848	21.627	12.17
20. Okinawa - IX	4/9-23/45	15	x	x				19,473	489	0.896	4,731	37	9.025	4.117	12.984	7.28
21. Okinawa-X	4/24 - 5/3/45	10	x				x	19,252	519	0.718	16,430	97	2.590	1.171	5.336	2.50
22. Okinawa-XI	5/3-4/45	1	x			x		16,430	97	19.257	12,757	252	2.056	1.294	0.385	0.70
23. Okinawa-XII	5/5-8/45	4	x	x				19,135	519	0.953	14,000	85	3.440	1.367	6.106	2.89
24. Okinawa-XIII	5/22-30/45	9	x				x	20,214	519	0.574	4,000	31	9.295	5.053	16.437	9.11
25. Okinawa-XIV	5/31-6/8/45	9	x				x	19,503	519	0.483	4,000	31	7.727	4.876	16.437	8.95
26. Okinawa-XV	6/9-18/45	10	x	x				18,958	519	0.798	2,500	20	44.160	7.583	25.955	14.03
KOREAN WAR																
27. Korea-I	9/16-18/50	1.5	x		x			10,960	125	2.920	15,158	719	0.497	0.723	0.175	0.36
28. Korea-II	9/18-21/50	4	x			x		16,626	1043	0.625	10,250	126	2.295	1.622	8.264	3.66
29. Korea-III	9/22-24/50	3	x				x	16,286	1043	0.526	8,960	[illegible]	6.110	1.818	10.381	4.34
30. Korea-IV	9/25-30/50	6	x				x	16,221	1043	0.119	7,085	67	3.180	2.289	13.557	5.97
31. Korea-V	3/7-9/51	3	x		x			25,516	1245	0.528	27,000	266	7.549	0.945	4.669	2.10
32. Korea-VI	2/3-7/51	5	x			x		29,006	1373	0.367	30,200	313	10.466	0.960	4.382	2.05
33. Korea-VII	4/3-5/51	3	x			x		26,021	1348	0.308	12,532	96	4.143	2.076	13.930	5.38
34. Korea-VIII	4/23-27/51	5	x				x	35,136	282	3.262	26,849	1348	0.546	1.309	0.209	0.52
35. Korea-IX	5/20-23/51	4	x			x		27,861	1348	0.234	38,000	304	3.143	0.733	4.431	1.80
36. Korea-X	6/1-2/51	2	x			x		37,000	253	1.893	13,790	699	0.551	2.690	0.363	0.99
37. Korea-XI	6/3-5/51	3	x		x			13,665	729	0.576	35,500	240	2.962	0.385	3.027	1.08

5. AREAS FOR FUTURE EXPLORATION

HERO is unaware of any comprehensive or authoritative study which undertakes reliable compilation of relevant combat data for 20th-Century conflicts in the fashion of Thomas L. Livermore in Numbers and Losses in the Civil War,[3] or G. Bodart in his famous, Militar-historisches Kriegs-Lexikon.[4] This fact has been noted in a valuable article in the September-October 1966 issue of Operations Research, "Combat Models and Historical Data: the U.S. Civil War,"[5] by Herbert K. Weiss. As Weiss says, there is need for such a survey of recent conflict for historical purposes, and above all for the development of realistic and useful combat models for analytical and predictive purposes for current combat, and for the development of war game inputs.

A first step in any such modern analysis could be a comprehensive review of the three sources cited in the previous paragraph. Additional sources which should be studied include several documents produced by RAC, particularly: RAC-TP-185, "Casualties and the Dynamics of Combat,"[6] by Robert J. Best; RAC-T-445, "Distribution of Combat Casualties by Causative Agents,"[7] by Geoffrey A. Burt, Janice T. Engleman, et al; and ORO-T-261, "The Structure of a Battle,"[8] by Robert J. Best. A number of British Army Operations Research Group documents should also be studied, including, "Battle Wastage Rates of Personnel in War,"[9] by H. G. Gee.

REFERENCES

1. War Gaming Handbook, Pamphlet No. 70-5, Sep 61. SECRET-SPECIAL HANDLING

2. Historical Evaluation and Research Organization. "Historical Trends Related to Weapon Lethality." Vol I, Annex I, U-48406. UNCLASSIFIED

3. Thomas L. Livermore, "Numbers and Losses in the Civil War in America, 1861-65," Civil War Centennial Series, Indiana University Press, Bloomington (1957). UNCLASSIFIED

4. G. Bodart, Militar-historisches Kreigs-Lexikon (1618-1905), C. W. Stern, pub., Wien and Leipzig, 1909. UNCLASSIFIED

5. Herbert K. Weiss, "Combat Models and Historical Data: the U.S. Civil War," Operations Research, Vol. 14, No. 5, Sep-Oct 66. UNCLASSIFIED

6. RAC-TP-185, "Casualties and the Dynamics of Combat," (U) by Robert J. Best. CONFIDENTIAL

7. RAC-T-445, "Distribution of Combat Casualties by Causative Agents," (U), by Jeffrey A. Burt, Janice T. Engleman, et al, CONFIDENTIAL

8. ORO-T-261, "The Structure of a Battle," by Robert J. Best. UNCLASSIFIED

9. H. G. Gee, "Battle Wastage Rates of Personnel in War," Rept 2/54, Army Operational Research Group (Great Britain), Feb 54. CONFIDENTIAL

Appendix C

RATES OF ADVANCE

Appendix C

RATES OF ADVANCE

1. PURPOSE

The purpose of this appendix is to explain the methodology by which the compatibility between the rates of advance employed in the TQGM, TWGM and DOM was established.

Application of the methodology is illustrated by the use of examples. Data, extracted from the models, are used in the examples. Sufficient data of this type are included herein to permit other comparisons without need for reference to the models themselves.

Other information in the following discussion was extracted from the three models. Model and paragraph reference to the source of the material in TBM-68 is not provided. However, the source is identifiable from information in the discussion.

2. COMPATIBILITY OF TQGM AND TWGM RATES OF ADVANCE

Both models employ division rates of advance per day including gains which might be made during the hours of darkness. Rates of advance used in the games are different because the models use different cycles of play and methodology. The TQGM plays a phase of operations usually consisting of at least several days of battle. Gains are computed for a phase by multiplying the appropriate division rate per day by the number of days in the phase. The model does not play probability of success factors. Accordingly, its rates reflect expected daily rates which might prevail over a period of at least several days. For example, if an attacker's rate of advance is three kilometers per day, his gain for a 4-day phase would be 12 kilometers.

The TWGM plays a normal cycle covering a 24-hour battle day. It does play probability of success factors. For each cycle of play, the success or failure of the attacker is determined by a probability of success factor and the draw of a random number. For example, if an attacker's probability of success factor remains at .75, he

might expect to win on an average of three times during the play of four battle days. If his rate of advance is four kilometers per day, his expected net gain after four days of battle would be 12 kilometers.

The compatibility between the rates in the two models is easily established. This is done by dividing the TQGM rate, or by multiplying the TWGM rate, by the appropriate probability of success factor. For example, in the TQGM, the rate for an armor attack with a force ratio of 2.0 to 1 against a prepared position is 1.7 kilometers per day. With the same force ratio in the TWGM, the attacker has a .65 probability of success. Dividing 1.7 by .65 gives 2.6, the rate shown in the TWGM for a similar attack. Other comparisons can be made in the same manner by applying probability of success factors shown in Table C-1 to the appropriate rate of advance shown in Table C-2. It should be noted that Table C-1 reflects the probability of success factors employed in the TWGM, and that Table C-2 includes the rates of advance which are employed in the TWGM and the TQGM.

Table C-1

PROBABILITY OF SUCCESS, ATTACKER VS DEFENDER

Force ratio atkr/dfdr	Posture of defender					
	Fortified position	Prepared position	Hasty position	Meeting engagement	Delaying action	With-drawal
1.0	.20	.30	.40	.50	.65	.75
1.5	.35	.50	.55	.62	.78	.88
2.0	.50	.65	.70	.75	.85	.95
2.5	.65	.70	.75	.82	.92	.96
3.0	.70	.75	.80	.85	.95	.97
3.5	.80	.82	.85	.88	.96	.98
4.0	.85	.87	.90	.91	.97	.98
4.5	.88	.89	.91	.93	.98	.99
5.0	.90	.91	.93	.95	.98	.99
6.0	.95	.96	.97	.97	.99	.99

Source: Table 2-6, Chap 2, Vol I (TWGM).

Table C-2

RATES OF ADVANCE (TWGM and TQGM) - TERRAIN TYPE A

TWGM DIVISION OPPOSED RATE OF ADVANCE - KILOMETERS PER DAY

Force ratio attacker/defender	Posture of defender										
	Fortified position	Prepared position		Hastily prepared position		Meeting engagement		Delaying action		Withdrawal	
	Inf & Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor
1.0	--	--	--	--	--	--	--	5.1	10.8	10.5	23.3
1.5	--	--	--	2.6	04.3	3.8	07.6	8.5	14.0	13.0	26.0
2.0	0.6	2.1	2.6	4.2	06.7	5.8	11.4	10.7	17.2	15.5	28.5
2.5	1.1	3.2	3.6	5.6	09.1	7.6	13.9	12.0	20.4	17.8	30.7
3.0	1.6	4.0	4.6	6.6	11.1	9.0	15.5	13.3	22.9	20.0	32.8
3.5	2.0	4.8	5.4	7.5	12.6	9.8	17.0	14.6	24.3	21.5	34.5
4.0	2.4	5.5	6.2	8.2	14.0	11.0	18.3	15.9	25.7	23.0	35.2
4.5	2.7	6.0	6.8	8.7	15.4	11.8	19.0	17.1	26.6	24.0	35.6
5.0	2.8	6.4	7.2	9.0	16.1	12.6	19.7	17.7	27.2	24.5	35.8

TQGM DIVISION MOVEMENT RATES (km/day) — NO BARRIERS

Force ratio attacker/defender	Posture of defender										
	Fortified position	Prepared position		Hastily prepared position		Meeting engagement		Delaying action		Withdrawal	
	Inf & Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor
1.0	--	--	--	--	--	--	--	3.4	07.0	7.9	17.5
1.5	--	--	--	1.4	2.3	2.5	04.7	6.8	10.9	11.4	22.9
2.0	0.3	1.4	1.7	3.0	4.7	4.8	08.6	9.1	14.8	14.7	27.1
2.5	0.8	2.2	2.6	4.2	6.8	6.2	11.4	11.0	18.7	17.1	29.5
3.0	1.2	3.0	3.5	5.3	8.9	7.7	13.2	12.6	21.4	19.4	31.8
3.5	1.6	3.8	4.4	6.4	10.7	9.0	15.0	14.0	23.3	21.1	33.8
4.0	2.0	4.6	5.3	7.4	12.6	10.0	15.7	15.4	24.9	22.5	34.5
4.5	2.3	5.3	6.0	7.9	14.0	11.0	17.7	16.8	26.0	23.8	35.2
5.0	2.5	5.8	6.5	8.4	15.0	12.0	18.7	17.3	26.7	24.3	35.4

Source: TWGM rates, Table 2-7, Chap 2, Vol I (TWGM). TQGM rates, Tables 2-4 and 2-6, Chap 2, Vol II (TQGM).

3. COMPATIBILITY OF DOM RATES OF ADVANCE WITH THOSE OF THE OTHER MODELS

Because of its shorter cycle of play (1 to 3 hours) and lower unit level of resolution, (company or battalion), the DOM uses battalion rates of advance on a per-hour basis. As the model does employ probability of success factors, it would be necessary to reduce its rates by the appropriate factors in making comparisons with TQGM rates. In the following discussion and examples, comparisons are made between the DOM and TWGM rates since computations are simplified by eliminating probability of success factors which are the same in both models.

Certain assumptions are made in showing the compatibility of rates in the two models. Each is discussed as a need for its use develops. The assumptions employed are believed reasonable. However, their validity under all conditions may be debatable. Should extensive play, local conditions, or other reason dictate, the assumptions may be changed accordingly without changing the methodology used in determining compatible rates. Rates for one of the models could be recomputed and comparable rates for the other could be determined by using the revised criteria in the methodology.

3.1 Differences in the Meaning of Division Rates Per Day and Battalion Rates Per Hour

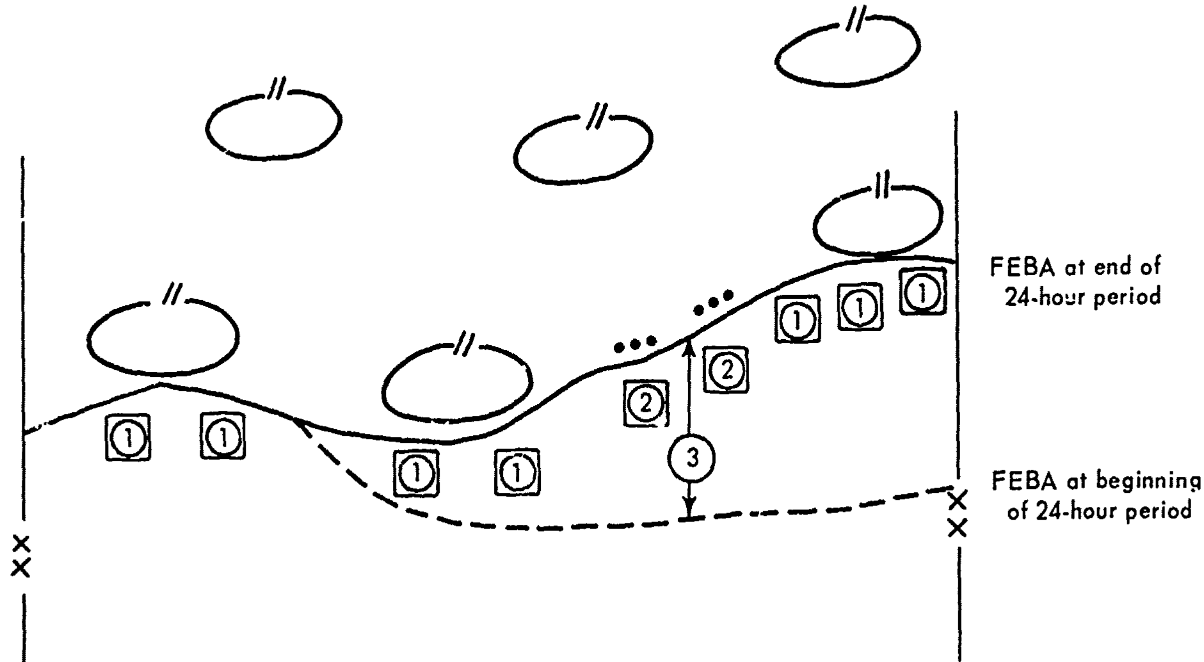


Fig. C-1—Schematic Illustration of a Situation at End of a 24-Hour Battle Period

Areas occupied by defending forces | 1 Battalions halted or attacking occupied areas
2 Battalions advancing against delaying actions | ••• Elements delaying attacking forces
3 Average gain during 24-hour period

The meaning of a division rate per day is shown in Fig. C-1 by the extent of advance indicated by line 3. The division rate reflects the average of the net gains made by all attacking battalions during a 24-hour period. It is unlikely that the division gain (line 3 in Fig. C-1) would be achieved by each of the attacking battalions. In some of the zones of action of attacking battalions, gains may be very small or no forward movement achieved. In other zones, advances may be in fast or slow spurts, with delays in between while attacking units are being reorganized, passed through or around, or held up by other causes. At the end of a day, in some zones units may be attacking organized defenses while in other zones units may be moving against delaying or withdrawal actions in areas between occupied positions. Obviously, DOM rates cannot be the net gain (line 3

in Fig. C-1) divided by 24. DOM rates are the average rates which prevail during those hours of a day when the individual battalions are actually moving forward. In the play of a game, as on the battlefield, the number of hours of forward movement will vary considerably for many reasons. However, it is reasonable to assume that the number of hours of movement is related to the attacker's force ratio and the posture of the defender. RAC-TP-76, January 1963, indicates this relationship. The information in the RAC document influenced the selection of the assumed numbers of hours of movement shown in Table C-3 which is used later in examples of compatibility. The table is considered to be applicable under favorable terrain conditions. Accordingly, in examples used to calculate compatible rates, Terrain Type A rates of advance have been used.

Table C-3

AVERAGE NUMBER OF HOURS PER DAY DURING WHICH BATTALION RATES OF ADVANCE MIGHT BE EXPECTED TO APPLY

Force ratio atkr/dfdr	Posture of defender					
	Fortified position	Prepared position	Hastily prepared position	Meeting engagement	Delaying action	Withdrawal
1.0	--	--	--	--	11.0	14.0
1.5	--	--	7.0	8.0	11.5	14.5
2.0	4.5	6.0	8.0	9.0	12.0	15.0
2.5	6.3	7.0	9.0	10.0	12.5	15.5
3.0	7.6	8.0	9.3	10.3	13.0	15.8
3.5	8.5	9.0	9.5	10.5	13.3	16.0

The DOM prescribes battalion rates of advance per hour during daylight with one half these rates applying at night. It is necessary to convert the DOM rates to average rates per hour, considering both daylight and night operations, before they can be compared to the TWGM 24-hour rates. Under the assumption that the ratio of daylight hours during which advances occur to night hours during which advances occur is two to one, the DOM average rates are equal to 2.5 times the daylight rate divided by three. The daylight rate is equal to 1.2 times the average rate.

3.2 Compatibility of Rates When Concepts of Defender's Postures are Similar

The concepts of the three models are similar when the defender is in a fortified position, delaying, or withdrawal posture. Each of the models, for a cycle of play, assume a uniform resistance throughout the depth of the area in which the action occurs. DOM average rates are multiplied by the appropriate number of hours of forward movement indicated in Table C-3 to determine the equivalent division rate, or division rates may be divided by the appropriate number of hours to determine a compatible DOM average rate. An equation for making comparisons between TWGM and DOM rates for the postures stated above is:

$$TWGM_r = DOM_{ar} \times H_m \text{ , or}$$

$$DOM_r = \frac{TWGM_r}{H_m} \times 1.2$$

where $TWGM_r$ = Rate per day as shown in TWGM

DOM_{ar} = DOM average rate per hour $= \frac{2.5\ DOM_r}{3}$

H_m = The number of hours of movement as indicated in Table C-3

DOM_r = Rate per hour during daylight as shown in DOM

$= DOM_{ar} \times 1.2$

When using the DOM rate to determine a compatible TWGM rate for an infantry attack with a force ratio of 2.0 against a delaying action, the factors in the equation become (see Table C-4):

$DOM_r = 1.07$

$DOM_{ar} = \frac{2.5 \times 1.07}{3} = .89$

$H_m = 12$

Table C-4

TWGM RATES - TERRAIN TYPE A

DIVISION OPPOSED RATE OF ADVANCE - KILOMETERS PER DAY[a]

Force ratio attacker/ defender	Posture of defender										
	Fortified position	Prepared position		Hastily prepared position		Meeting engagement		Delaying action		Withdrawal	
	Inf & Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor
1.0	--	--	--	--	--	--	--	5.1	10.8	10.5	23.3
1.5	--	--	--	2.6	04.3	3.8	07.6	8.5	14.0	13.0	26.0
2.0	0.6	2.1	2.6	4.2	06.7	5.8	11.4	10.7	17.2	15.5	28.5
2.5	1.1	3.2	3.6	5.6	09.1	7.6	13.9	12.0	20.4	17.8	30.7
3.0	1.6	4.0	4.6	6.6	11.1	9.0	15.5	13.3	22.9	20.0	32.8
3.5	2.0	4.8	5.4	7.5	12.6	9.8	17.0	14.6	24.3	21.5	34.5
4.0	2.4	5.5	6.2	8.2	14.0	11.0	18.3	15.9	25.7	23.0	35.2
4.	2.7	6.0	6.8	8.7	15.4	11.8	19.0	17.1	26.6	24.0	35.6
5.0	2.8	6.4	7.2	9.0	16.1	12.6	19.7	17.7	27.2	24.5	35.8

DOM RATES - TERRAIN TYPE A
BATTALION OPPOSED RATE OF ADVANCE - KILOMETERS PER HOUR

Force ratio attacker/ defender	Posture of defender										
	Fortified position	Prepared position		Hastily prepared position		Meeting engagement		Delaying action		Withdrawal	
	Inf & Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor	Inf	Armor
1.0	.05	.08	.08	.15	0.20	0.17	0.40	0.55	1.08	0.90	2.01
1.5	.11	.15	.15	.26	0.37	0.33	0.80	0.89	1.45	1.08	2.15
2.0	.16	.21	.21	.36	0.55	0.48	1.11	1.07	1.72	1.24	2.28
2.5	.21	.26	.26	.44	0.71	0.65	1.29	1.16	1.98	1.38	2.39
3.0	.25	.30	.30	.52	0.87	0.80	1.44	1.23	2.10	1.51	2.49
3.5	.28	.33	.33	.60	1.03	0.87	1.58	1.30	2.20	1.61	2.58

[a]For night or low visibility use one-half of day rate.

Source: TWGM rates, Table 2-7, Chap. 2, Vol I (TWGM). DOM rates, Chap. 5, Vol III (DOM).

$TWGM_r = .89 \times 12 = 10.7$ which is the rate shown in TWGM tables.

Other comparisons can be made in a similar manner.

It will be noted from Table C-4 that the DOM establishes rates of advance for force ratios of up to 3.5 to 1, while the TWGM, with its much more extensive area of conflict, establishes rates for force ratios of up to 5 to 1. The TWGM rates for the higher force ratios were taken from graphs, after extending curves established by plotting compatible rates which were determined through the methodology herein for force ratios up to 3.5 to 1.

Rates for TWGM and DOM in Table C-4 reflect an assumption that in attacks against a fortified position, armor rates would not exceed those of infantry. The same assumption pertains to attacks against the occupied areas of a prepared position. This too is reflected in the DOM rates. Although, also reflected in the TWGM rates, application of the assumption is not as apparent because the TWGM rates against a prepared position show higher rates for armor than for infantry. The reason for this is illustrated in Fig. C-2, and is explained in para 3.3.

3.3 Difference in Model Concepts When Opposed by Prepared Position, Hastily Prepared Position, or Meeting Engagement Postures

When a defender is in one of these postures, differences in levels of resolution between the DOM and the other models cause the models to differ in the way they play the resistance encountered throughout the depth of a division's defensive area. The TQGM and the TWGM still assume a uniform resistance throughout the depth of the defensive area. However, in the DOM, the attacker is assumed to encounter successive bands of defended positions separated by less strongly defended sectors.

Fig. C-2 is helpful in explaining this difference.

In TWGM and TQGM the entire depth of the division defensive area (3 in Fig. C-2) is played as a single posture. The posture (prepared position, hastily prepared position, or meeting engagement) is determined by the extent of protective measures in and around the organized portions of the defensive areas 1 in Fig. C-2.

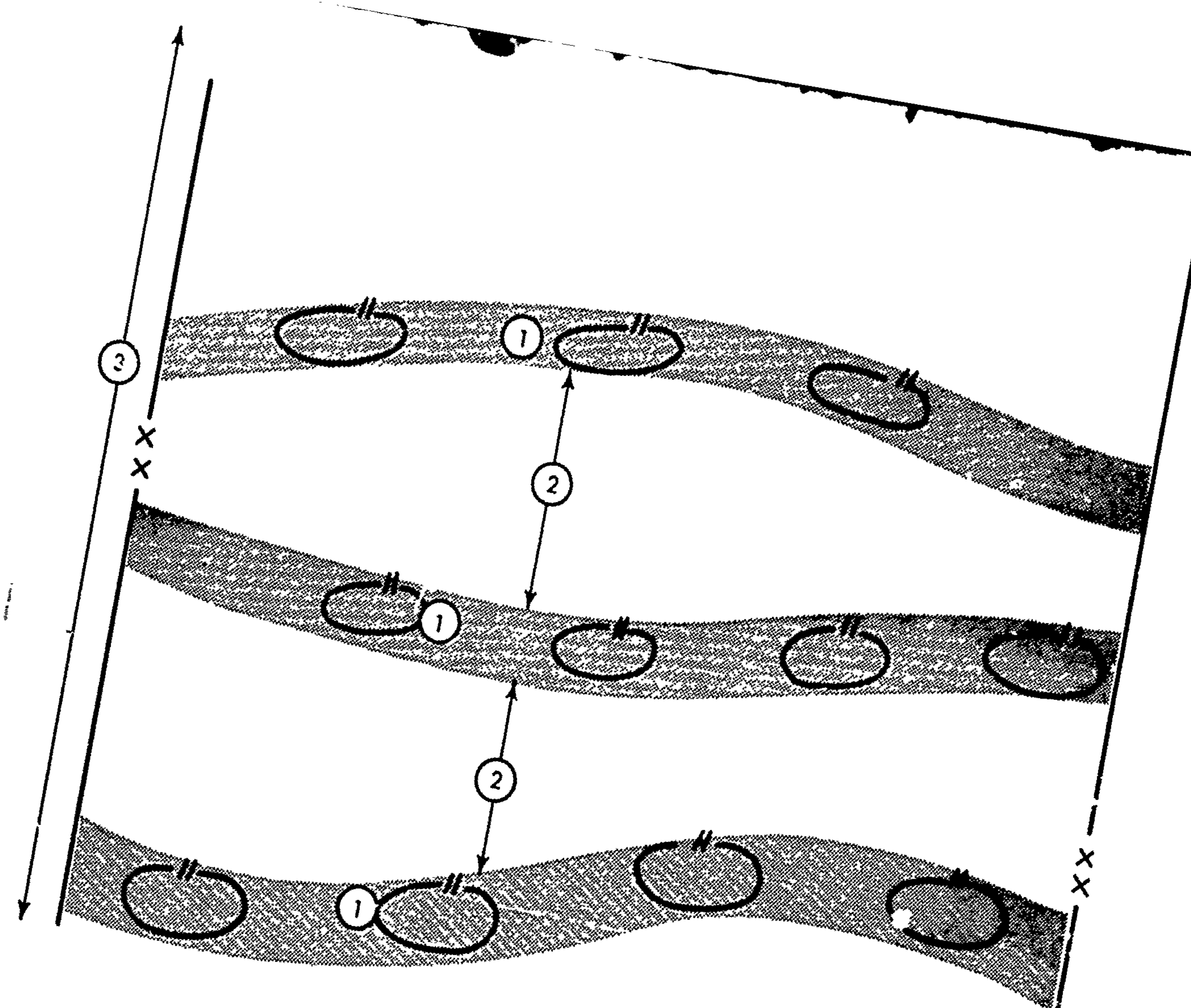


Fig. C-2—Schematic Illustration of a Part of a Division Defensive Area

1 Organized defensive areas
Positions occupied or to be occupied
2 Areas between organized defensive areas

The DOM determines posture in the same manner and plays the appropriate posture while attacking the organized defensive area, (1 in Fig. C-2). The posture played in the areas between defensive areas (2 in Fig. C-2) is dependent on player reaction, but usually is played as a delaying or withdrawal action. In later computations on compatiability, play in this area is considered a delaying action. The depth of area (2 in Fig. C-2) is assumed to average twice the depth of the area 1 in Fig. C-2. Under this assumption, in an attacker's advance over a period of time, two-thirds of the total distance advanced will have been in the areas between positions (2 in Fig. C-2), and one-third of the distance within the defensive areas themselves (1 in Fig. C-2). Under this and previous assumptions, an equation for determining compatibility is:

$$TWGM_r = (DOM_{arp} \times H_m \times P_{tmp}) + (DOM_{ard} \times H_m \times P_{tmd})$$

where $TWGM_r$ = TWGM division rate per day (TWGM rate in Table C-4)

DOM_{arp} = DOM battalion average rate per hour against the posture of the defender ((1) in Fig. C-2) = $\frac{2.5}{3} DOM_{rp}$

DOM_{rp} = DOM battalion rate per hour during daylight against posture of defender. (DOM rate in Table C-4)

H_m = Total number of hours of a 24-hour period during which forward movement of battalions occur (Table C-3)

P_{tmp} = Percentage of H_m spent in moving against the organized area of the defender ((1) in Fig. C-2)

$$= \left(\frac{1}{DOM_{arp}}\right) \div \left[\left(\frac{1}{DOM_{arp}}\right) + \left(\frac{2}{DOM_{ard}}\right)\right].$$

This equation is based on assumption above pertaining to depth of areas.

where DOM_{ard} = DOM battalion average rate per hour against a delaying action $= \frac{DOM_{rd}}{1.2}$

DOM_{rd} = DOM battalion rate per hour during daylight against delaying action (DOM rate in Table C-4)

P_{tmd} = Percentage of H_m spent in moving against delaying action = 1 (100 percent) — P_{tmp}

When using DOM rates to determine the equivalent TWGM rates, all factors in the above equation can be computed under previous assumptions. For example, in comparing armor rates for a force ratio of 2.5 to 1 against a hastily prepared position the factors in the equation become:

$$DOM_{arp} = \frac{2.5 \times .71}{3} = .59$$

$$H_m = 9$$

$$P_{tmp} = \left(\frac{1}{.59}\right) \div \left(\frac{1}{.59} + \frac{2}{1.63}\right) = \frac{1.69}{1.69 + 1.23} = .58$$

$$DOM_{ard} = \frac{2.5 \times 1.96}{3} = 1.63$$

$$P_{tmd} = 1 - .58 = .42$$

$$TWGM_r = (.59 \times 9 \times .58) + (1.63 \times 9 \times .42) = 3.08 + 6.16 = 9.24$$

which is approximately equal to 9.1 shown in the TWGM table.

When using TWGM rates to determine the equivalent DOM rates, the computations can be simplified by first computing DOM delay rates as shown in para 3.2 and then applying the following equation:

$$TWGM_r = (DOM_{ard} \times N_{hmd}) + (DOM_{arp} \times N_{hmp})$$

N_{hmd} = Number of hours moving against delaying action = $\frac{2\ TWGM_r}{3} \div DOM_{ard}$.

Note that $\frac{2\ TWGM_r}{3}$ is based on the assumption pertaining to depths of areas.

N_{hmp} = Number of hours moving against the organized areas of the defender

((1) in Fig. C-2) = $H_m - N_{hmd}$

$$DOM_{arp} = \frac{TWGM}{3} \div H_m - N_{hmd}$$

In using the equation to determine the compatibility of DOM rates with those of TWGM for an infantry attack with a force ratio of 2.0 in a meeting engagement, the factors in the equation become:

$$TWGM_r = 5.8$$

$$DOM_{ard} = \frac{1.07}{1.2} = .89$$

$$H_m = 9$$

$$N_{hmd} = \left(\frac{2 \times 5.8}{3}\right) \div .89 = 4.35$$

$$N_{hmp} = 9 - 4.35 = 4.65$$

$$DOM_{arp} = \left(\frac{5.8}{3}\right) \div 4.65 = \frac{1.93}{4.65} = .42$$

$DOM_{rp} = .42 \times 1.2 = .50$ which is compatible with the rate of .49 shown in the DOM table.

4. COMPATIBILITY OF RATES IN TERRAIN TYPES B AND C

The rates of advance in the three models for Terrain Types B and C are reduced from the rates for Terrain Type A and are based on the extent of the similar handicaps imposed by similar terrain definitions in the three models.

In Terrain Type B, infantry rates were reduced to 70 percent and armor rates to 60 percent of their rates in Terrain Type A.

In Terrain Type C, infantry was reduced to 40 percent of its rates in Terrain Type A. Appreciable gains by armor were considered unlikely when opposed by resistance greater than that expected during withdrawals.

Appendix D

WORK ACCOMPLISHMENTS

Appendix D

WORK ACCOMPLISHMENTS

Section 1

SUMMARY OF ACCOMPLISHMENTS

1.1 REVISION OF THEATER BATTLE MODEL-63

The general objective of the TBM-68 project was to revise TBM-63. The revision was further described as the task of redesigning, refining, and updating TBM-63 with emphasis on quality improvements in order to make this manual, joint, limited war gaming model more flexible and universally acceptable to meet the varying war gaming requirements of the Joint War Games Agency, the unified and specified commands, and the Services.

1.1.1 Redesign

The "redesign" requirement was met by providing a separate gaming manual for each of the five models included in the project. Each gaming manual is complete and includes all information concerning game procedures necessary for player and control personnel. Each chapter of the gaming manuals covers a specific submodel and includes pregame requirements, player instructions, and control instructions and procedures appropriate to the play of that submodel.

The Theater Quick Game Model was prepared to provide a capability to conduct a quick analysis of a limited war situation.

A first step toward future computerization of the TBM-68 models was taken by providing flow diagrams for the submodels, as appropriate.

1.1.2 Refine

The refinement of TBM-63 consisted of:

Expanding the coverage of the theater game air submodel to include: tactical air—air superiority and air defense operations, close air support, and armed aerial reconnaissance.

Providing Chemical-Biological submodels for the theater and division level games.

Providing a model for the war gaming of an amphibious assault operation.

Providing a model for the war gaming of the counter-guerrilla aspects of unconventional war operations.

1.1.3 Update

TBM-63 was updated by recalculating and expanding the Indexes of Fire Power Potential (IFPs) to include all current types of organization and weapons systems. IFPs are provided for all company-size units that might be reasonably involved in war game play.

A technique was devised for calculating the IFPs for tactical air close-air-support weapons and for naval gunfire munitions that makes them compatible with the IFPs for ground units.

1.2 TEST WAR GAMES

As required by the Technical Work Statement, test war games of the various models were conducted at RAC during the periods 1 Feb 67 to 10 May 67 and 31 Jul 67 to 25 Aug 67.

1.2.1 Initial Test Games

1.2.1.1 Theater War Game Model (TWGM) Test. The test game of the TWGM was conducted during the period 1 Feb 67 to 1 Mar 67.

Military personnel were provided, by arrangements of JWGA, to act as test players during the test games as follows:

COL H. H. Stirling, USMC (MCLFDC)
LTC J. R. Sain, USA (STAG)
LTC J. H. Thorne, USA (STAG)
LT W. F. Flannery, USN (OPO6CIF)
LTC J. S. Carson, USAF (AFXPS)
LTC P. J. Milian, USAF (AFXOP)

MAJ P. W. Gower, USAF (AFXSA)
LTC A. C. Evers, USAF (JWGA)
LTC W. L. Knapp, USA (JWGA)
Mr. F. T. Trippi, Civ (NMCSSC)

1.2.1.2 Counterguerrilla Warfare Model (CGWM). The test game of the CGWM was conducted during the period 3-22 Mar 67. Military personnel participating in the CGWM test game were:

LTC J. R. Sain, USA (STAG)
LTC J. H. Thorne, USA (STAG)
LTC A. C. Evers, USAF (JWGA)

1.2.1.3 Division Operations Model (DOM). The test game of the DOM was conducted during the period 3-31 Mar 67. Military personnel participating in the DOM test game were:

COL H. H. Stirling, USMC (MCLFDC)
LTC W. L. Knapp, USA (JWGA)
LT W. F. Flannery, USN (OPO6C1F)

1.2.1.4 Amphibious Warfare Model (AWM). The test game of the AWM was held during the period 24-31 Mar 67. Military personnel participating in the AWM test game were:

COL H. H. Stirling, USMC (MCLFDC)
LTC W. L. Knapp, USA (JWGA)
LT W. F. Flannery, USN (OPO6C1F)
LTC J. R. Sain, USA (STAG)
LTC J. H. Thorne, USA (STAG)
LTC A. C. Evers, USAF (JWGA)

1.2.1.5 Partial Retest Games. A series of partial retest games of the TWGM, DOM, and AWM were conducted during the period 1 Apr 67 to 10 May 67.

1.2.2 Retest Games

After modifications and revisions of the models to correct deficiencies revealed by the initial test games a series of retest games was conducted during the period 31 Jul 67 to 25 Aug 67.

1.2.2.1 TWGM Air Submodel Retest. A retest of the Air Submodel of the TWGM was conducted during the period 31 Jul 67 to 14 Aug 67. Military personnel participating in this retest were:

LTC J. H. Thorne, USA (STAG)
MAJ R. R. Bolt, USA (STAG)
CAPT M. Brambella, USN (BUPERS)
COL H. H. Stirling, USMC (MCLFDC)
LTC A. C. Evers, USAF (JWGA)
LTC G. Elvey, USAF (AFGOA)
MAJ A. Oliver, USAF (AFXOP)
MAJ R. J. Smith, USAF (AFCSA)
MAJ D. C. Peterson, USAF (AFXPD)

1.2.2.2 Theater Quick Game Model (TQGM). The first test game for the TQGM was conducted during the period 14-18 Aug 67. Military personnel participating in this test game were:

COL H. H. Stirling, USMC (MCLFDC)
LT W. F. Flannery, USN (OP06CIF)
LTC J. H. Thorne, USA (STAG)
Mr. J. J. Onufrak, Civ (STAG)
MAJ R. J. Smith, USAF (AFCSA)
MAJ A. Oliver, USAF (AFXOP)
LTC A. C. Evers, USAF (JWGA)
LTC T. J. Lepski, USA (JWGA)

1.2.2.3 AWM and DOM Retest. The joint retest of the AWM and the DOM was conducted during the period 21-25 Aug 67. Military personnel participating in this retest were:

COL H. H. Stirling, USMC (MCLFDC)
CAPT W. J. Foley, USN (BUPERS)
LT W. F. Flannery, USN (OP06CIF)
LTC H. H. Thorne, USA (STAG)
LTC J. W. Curtis, USA (STAG)
Mr. T. S. Kitchell, Civ (STAG)
MAJ R. J. Smith, USAF (AFCSA)
MAJ A. Oliver, USAF (AFXOP)
COL J. Leon, USMC (JWGA)
LTC T. J. Lepski, USA (JWGA)

1.3 DOCUMENTATION

The documents published in execution of the TBM-68 project are as follows:

Document	Pages	Copies Distributed
Vol I - Part I, Theater War Game Model, Chaps 1, 2, 3	343	135
Vol I - Part II, TWGM, Chaps 4, 5, 6, 7	249	135
Vol I - Part III, TWGM, Appendixes	349	135
Vol IF - Part I, TWGM, Chaps 1, 2, 3, (Foreign)	343	40
Vol IF - Part II, TWGM, Chaps 4, 5, 6, 7, (Foreign)	249	40
Vol IF - Part III, TWGM, Appendixes, (Foreign)	210	40
Vol II - Theater Quick Game Model	214	135
Vol IIF - TQGM (Foreign)	117	40
Vol III - Division Operations Model	504	135
Vol IIIF - DOM (Foreign)	370	40
Vol IV - Counterguerrilla Warfare Model	341	135
Vol IVF - CGWM (Foreign)	194	40
Vol V - Part I, Amphibious Warfare Model	343	135
Vol V - Part II, AWM, Appendixes	212	135
Vol VF - AWM (Foreign)	415	40
Vol VI - COFRAM Supplement	62	60
Vol VII - Technical Report	177	4
Totals	4,732	1,424

1.4 MANAGEMENT

The management system established to control the TBM-68 project included a Joint Ad Hoc Steering Committee, a project officer designated by Defense Communication Agency National Military Command System Support Center (NMCSSC), a management plan prepared by RAC, and a schedule of monthly reports published by RAC.

The organization for management is shown in Fig. D-1.

1.4.1 Joint Ad Hoc Steering Committee

A Joint Ad Hoc Steering Committee (JAHSC) was organized to provide overall monitorship of the TBM-68 project. Membership on the JAHSC was as shown in Table D-1.

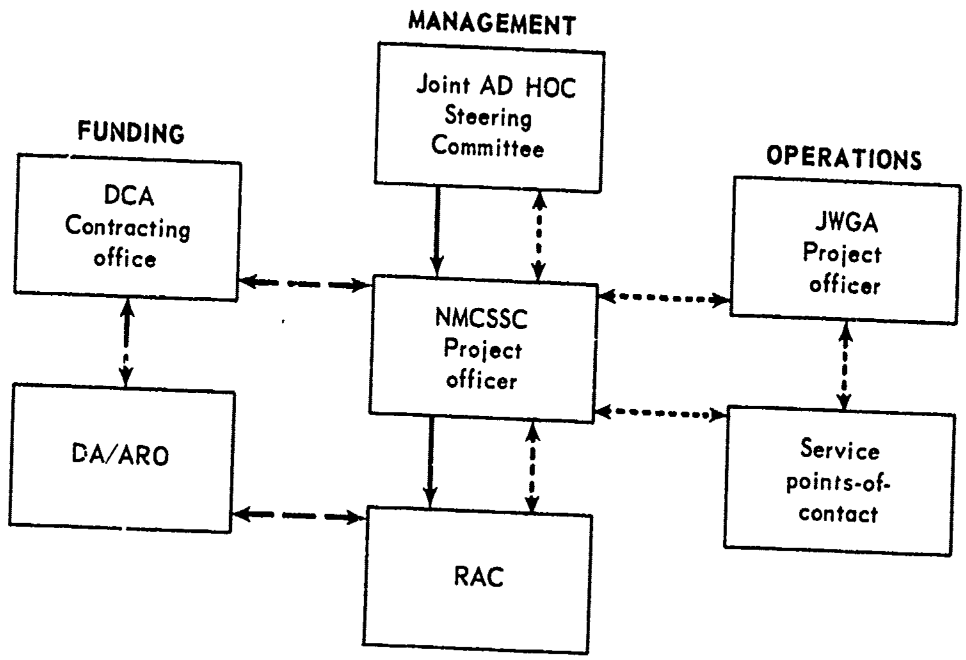


Fig. D1—Organization for Management

—— Direction ------ Coordination — — Contractual matters

Table D-1

MEMBERSHIP — JOINT AD HOC STEERING COMMITTEE

	Name	Rank/Service	Committee duty	Regular duty
1.	James Leon	COL, USMC	Chairman	Mbr, LWD, JWGA
	A. C. Evers	LTC, USAF	Alt Chm	Mbr, LWD, JWGA
2.	Frank T. Trippi	GS-13 NMCSSC	NMCSSC Proj Off	OR Analyst, NMCSSC
3.	J. R. Sain (25 Aug 66-15 May 67)	LTC, USA	Mbr, USA Rep	Ch, Spc Br, STAG
	J. H. Thorne (26 May 67-15 Apr 68)	LTC, USA	Mbr, USA Rep	Ch, Prog Br, STAG
	C. W. Cyr (25 Aug 66-11 Oct 66)	COL, USA	Alt Mbr	Ch, WG Br, DCSOPS
	W. M. Stevenson (1 Dec 66-9 Jan 67)	MAJ, USA	Alt Mbr	WG BR, DCSOPS
	B. Worthen (7 Mar 67-15 Apr 68)	LTC, USA	Alt Mbr	WG Br, DCSOPS
4.	R. D. Kaiser	CDR, USN	Mbr, USN Rep	OPO6CIE
	F. S. Schick, Jr. (25 Aug 66-7 Mar 67)	LTC, USMC	Alt Mbr	OPO6CIE
	W. F. Flannery (26 May 67-15 Apr 68)	LT, USN	Alb Mbr	OPO6CIE
5.	H. K. Leland (25 Aug 66-7 Mar 67)	COL, USAF	Mbr, USAF Rep	AFXSA
	P. W. Gower (26 May 67-15 Apr 68)	MAJ, USAF	Mbr, USAF Rep	AFCSAG
	W. W. McMahon (25 Aug 66-26 May 67)	CAPT, USAF	Alt Mbr	AFXSA
	D. M. Nagel (11 Aug 67-15 Apr 68)	MAJ, USAF	Alt Mbr	AFCSAG
6.	B. E. Clark (25 Aug 66- 7 Mar 67)	MAJ, USMC	Mbr, USMC Rep	Ops Anal MCLFDC
	H. H. Stirling (26 May 67-15 Apr 68)	COL, USMC	Mbr, USMC Rep	MCLFDC
	B. B. Spicer	LTC, USMC	Alt Mbr,	MCLFDC

	Name	Rank/Service	Committee duty	Regular duty
7.	L. J. Dondero	RAC	Head, Military Gaming Dept	RAC
	R. E. Zimmerman	RAC	Contr Princ Invest	RAC
	P. D. Phillips (25 Aug 66-1 Dec 66)	RAC (BG, Ret)	Contr Dep Invest	RAC
	N. W. Parsons (15 Dec 66-15 Apr 68)	RAC (LTC, Ret)	Contr Dep Invest	RAC
8.	J. J. Churchill (25 Aug 66-26 May 67)	LTC, USA	Observer	OCRD, DA
	P. Lawrence (30 Aug 67-15 Apr 68)	LTC, USA	Observer	OCRD, DA

1.4.2 NMCSSC Project Officer

A project officer was designated with the responsibility for planning, scheduling, initiation, coordination, and supervision of the NMCSSC contractual support of the project. To assist in the execution of these duties, office facilities were made available to the project officer at the RAC facility.

1.4.3 Management Plan

RAC prepared a management plan which included a detailed schedule of intended task performance, details of management controls, the organization to accomplish the project, and list of the technical personnel to be assigned to the project. The management plan also included modified PERT charts and milestone charts for the project as a whole and for each of the major models.

1.4.4 Reports

RAC submitted monthly reports outlining for each major model the achievements, delays encountered, manpower employed, personnel changes, and visits during the month. Funds and manpower expended during the month were also reported.

1.5 CONFERENCES

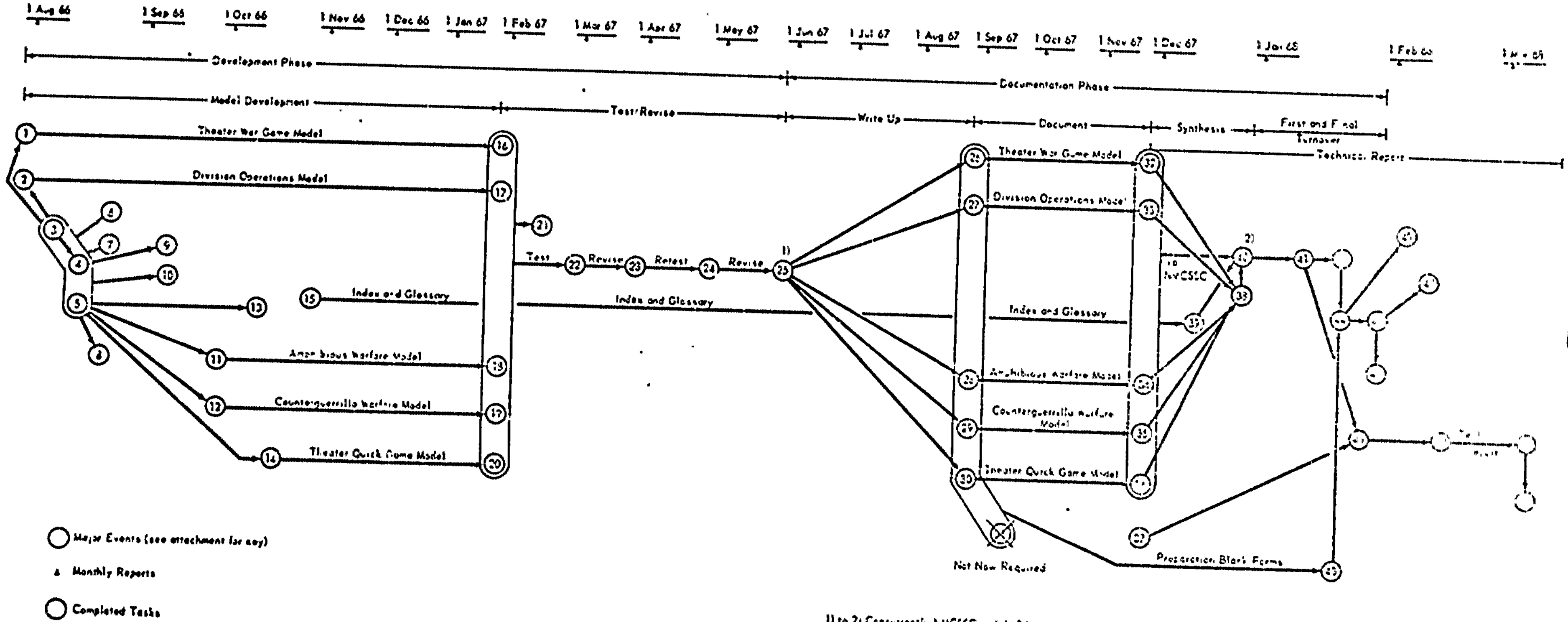
Conferences and meetings of the JAHSC for guidance to RAC and resolution of various questions were held as follows:

Date	Purpose
25 Aug 66	Initial meeting of JAHSC. Comprehensive review of TBM-63. Briefing of Technical Work Statement. Briefing of RAC Management Plan.
1 Sep 66	Meeting at JWGA to clarify meaning of term, "Navy Support" for TWGM.
11 Oct 66	Meeting of JAHSC to discuss RAC concept statements for the TWGM, DOM, AWM, and CGWM.
28 Nov 66	Conference at RAC to discuss Service comments on the concept statements of Ground Combat and Combat Support, Air, Intelligence, and Logistic Submodels of TWGM.
21 Dec 66	Conference at RAC to discuss Service comments on the Nuclear and Chemical-Biological Submodels of TWGM.
9 Jan 67	The third JAHSC meeting was held at RAC for briefings on the TWGM submodels.
20 Jan 67	Conference at RAC for briefings on the DOM submodels.
27 Jan 67	Conference at RAC for briefing on the CGWM submodels.
3 Feb 67	Conference at RAC with Navy and USMC members of JAHSC to discuss the Naval Support Submodel of TWGM.
2 Mar 67	Conference at RAC to discuss deficiencies of TWGM Air Submodel revealed by initial test games.
8 Mar 67	The fourth JAHSC meeting was held at RAC to discuss proposed changes in handling Air IFPs in battle assessments.

Date	Purpose
31 May 67	Conference at RAC to discuss revisions of Air Sub-model of TWGM.
6 Jun 67	The fifth meeting of the JAHSC was held at RAC to review the results of the initial test games and proposals for revisions and retest games.
30 Aug 67	The sixth JAHSC meeting was held at RAC to review the results of the retest games.
11 Oct 67	A special JAHSC meeting was held to consider a RAC proposal concerning the foreign version of AWM.
12 Dec 67	A conference was held at RAC to discuss the Navy and USMC comments on the IFP procedure.
5 Feb 68	A conference was held at RAC to discuss changes in the technique of calculation of Close Air Support and Naval Gunfire IFP.

Section 2

OVERALL PERT TYPE CHART



1) to 2) Concurrently, NMCSSC and JWGA review and approve drafts of all volumes as they are completed

Section 3

TASK LIST KEY TO MODIFIED PERT CHART

Task Number	Description	Timing	Major Milestones	Actual Date of Milestone
1.	Begin Theater War Game Model	1 Aug 66		1 Aug 66
2.	Begin Division Operations Model	1 Aug 66		1 Aug 66
3.	Issue comprehensive directive and coordinating instructions to staff	10 Aug 66		16 Aug 66
4.	Complete general PERT-type and milestone charts for overall project. Outline publication schedule.	15 Aug 66		10 Aug 66
5.	Submit Management Plan	15 Aug 66		15 Aug 66
6.	Complete PERT-type and milestone charts for Theater War Game Model and all submodels	20 Aug 66		29 Aug 66
7.	Same as 6 for Division Operations Model and all submodels	20 Aug 66		24 Aug 66
8.	Participate in comprehensive review of TBM-63	25 Aug 66		25 Aug 66
9.	Same as 6 for Amphibious Warfare Model and all submodels	15 Sept 66		15 Sept 66
10.	Same as 6 for Counterguerrilla Warfare Model and all submodels	15 Sept 66		15 Sept 66
11.	Begin Amphibious Warfare Model	1 Oct 66	X	8 Aug 66
12.	Begin Counterguerrilla Warfare Model	1 Oct 66	X	1 Sept 66
13.	Complete PERT-type and Milestone Charts for Theater Quick Game and all submodels	15 Oct 66		15 Oct 66
14.	Begin Theater Quick Game Model	1 Nov 66	X	30 Nov 66
15.	Begin Index (with extensive cross-referencing) and Glossary	1 Nov 66		1 Nov 66

TASK LIST KEY TO MODIFIED PERT CHART (continued)

Task Number	Description	Timing	Major Milestones	Actual Date of Milestone
16.	Complete Theater War Game Model	31 Jan 67	X	15 Jul 67
17.	Complete Division Operations Model	31 Jan 67	X	26 Apr 67
18.	Complete Amphibious Warfare Model	31 Jan 67	X	21 Apr 67
19.	Complete Counterguerrilla Warfare Model	31 Jan 67	X	31 Jan 67
20.	Complete Theater Quick Game Model	31 Jan 67	X	28 Apr 67
21.	Test Theater War Game Model for consistency with Division Operations, Amphibious Warfare, and Counterguerrilla Models	10 Feb 67	X	15 Mar 67
22.	Conduct a test war game using the initial draft of TBM-68. Test validity of methodologies in basic and submodels, assess interactions of various components of the model, test readability and understandability to players. (Test game of TWGM only)	28 Feb 67	X	28 Feb 67
	Test game of CGWM			24 Mar 67
	Test game of DOM			24 Mar 67
	Test game of AWM			31 Mar 67
23.	Revise TBM-68 based on game play (TWGM only)	Mar 67		31 Mar 67
	Revise DOM			15 Apr 67
	Revise CGWM			20 Apr 67
	Revise AWM			20 Apr 67
24.	Retest TBM-68	Apr 67	X	
	Retest DOM			28 Apr 67
	Retest CGWM			28 Apr 67
	Retest AWM			28 Apr 67

TASK LIST KEY TO MODIFIED PERT CHART (continued)

Task Number	Description	Timing	Major Milestones	Actual Date of Milestone
25.	Revise TBM-68 based on Retest	May 67	X	31 Aug 67
26.	Write up Theater War Game Model including any sanitization necessary and COFRAM. Include state-of-the-art improvements. Complete appendixes for Technical Report.	31 Aug 67	X	31 Dec 67
27.	Same for Division Operations Model	31 Aug 67	X	31 Oct 67
28.	Same for Amphibious Warfare Model	31 Aug 67	X	15 Feb 68
29.	Same for Counterguerrilla Warfare Model	31 Aug 67	X	1 Oct 67
30.	Same for Theater Quick Game Model	31 Aug 67	X	5 Oct 67
31.	Get final format approval from NMCSSC if automated documentation is to be used.	Sep 67		Not now required
32.	Complete documentation for Theater War Game Model. Develop clear step-by-step examples. Include sanitized version and COFRAM section.	1 Dec 67	X	5 Mar 68
33.	Same as 32 for Division Operations Model	1 Dec 67	X	5 Jan 68
34.	Same as 32 for Amphibious Warfare Model	1 Dec 67	X	31 Mar 68
35.	Same as 32 for Counterguerrilla Warfare Model	1 Dec 67	X	20 Oct 67
36.	Same as 32 for Theater Quick Game Model	1 Dec 67	X	21 Oct 67

TASK LIST KEY TO MODIFIED PERT CHART (continued)

Task Number	Description	Timing	Major Milestones	Actual Date of Milestone
37.	Begin final draft of Technical Report	1 Dec 67		1 Dec 67
38.	Prepare abstract/summary of contents of each volume for inclusion therewith	15-31 Dec 67		15-31 Jan 68
39.	Complete Index and Glossary	15 Dec 67	X	15 Dec 67
40.	Submit reproducible mats on documentation to NMCSSC Project Officer (PO) for final review and approval. Include Index and Glossary. Include US, Sanitized and COFRAM parts.	1 Jan 68	X	
	TWGM			8 Mar 68
	TQGM			25 Oct 67
	DOM			8 Jan 68
	CGWM			24 Oct 67
	AWM			2 Apr 68
	COFRAM Supplement			11 Jan 68
41.	Receive NMCSSC PO comments on final mats on documentation	15 Jan 68	X	
	TWGM			7 May 68
	TQGM			7 Dec 67
	DOM			23 Feb 68
	CGWM			22 Nov 67
	AWM			10 Jul 68
	COFRAM Supplement			29 Feb 68
42.	Make changes/corrections in final mats	15-20 Jan 68		10 Dec 67 to 15 Feb 69
43.	Prepare blank forms for mass production of legible copies	1-20 Jan 68		1-15 Feb 68
44.	Submit TBM-68 to printer (less Technical Report)	20 Jan 68	X	

TASK LIST KEY TO MODIFIED PERT CHART (continued)

Task Number	Description	Timing	Major Milestones	Actual Date of Milestone
44. (contd)	TWGM			26 Feb 69
	TQGM			22 Mar 68
	DOM			14 Aug 68
	CGWM			19 Mar 68
	AWM			10 Dec 68
	COFRAM Supplement			10 Jul 68
45.	Complete draft of final Technical Report and submit to NMCSSC PO in 3 copies.	15-31 Jan 68	X	10 Feb 69
46.	Print final documentation as follows:	20-31 Jan 68	X	TWGM 21 Apr 69
				TQGM 15 May 68
				DOM 30 Sep 68
	TBM-68 (US Version), 135 copies			CGWM 19 Apr 68
	TBM-68 (Sanitized Version), 40 copies			AWM 2 Jan 69
	TBM-68 (COFRAM Section), 60 copies			COFRAM 19 Jul 68
47.	Transmit 20 copies of each volume of final version of documentation to Defense Documentation Center, Cameron Station, Virginia.	1 Feb 68	X	TWGM 30 Apr 69
				TQGM 11 Jun 68
				DOM 18 Nov 68
				CGWM 31 May 68
				AWM 28 Mar 69
48.	Furnish magnetic tapes, punch cards, maps, scenarios, blank forms, and charts used or purchased to NMCSSC PO.	Feb 68		Not required
49.	Prepare for shipment and distribute final documentation to such agencies as directed by NMCSSC PO.	Feb 68		Shipped in bulk to JWGA
50.	Receive from NMCSSC PO comments on final draft Technical Report.	15 Feb 68	X	20 Mar 69
51.	Review and print Technical Report on basis of corrections and changes received from NMCSSC PO.	15 Feb - 15 Mar 68		15 Apr 69

Section 4

OVERALL NMCS SUPPORT CENTER MILESTONE CHART

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

PLANS & POLICY OFFICE			
CLASSIFICATION	SCHEDULE NO.		
	AS OF DATE:		
	PAGE OF		
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PROCUREMENT			
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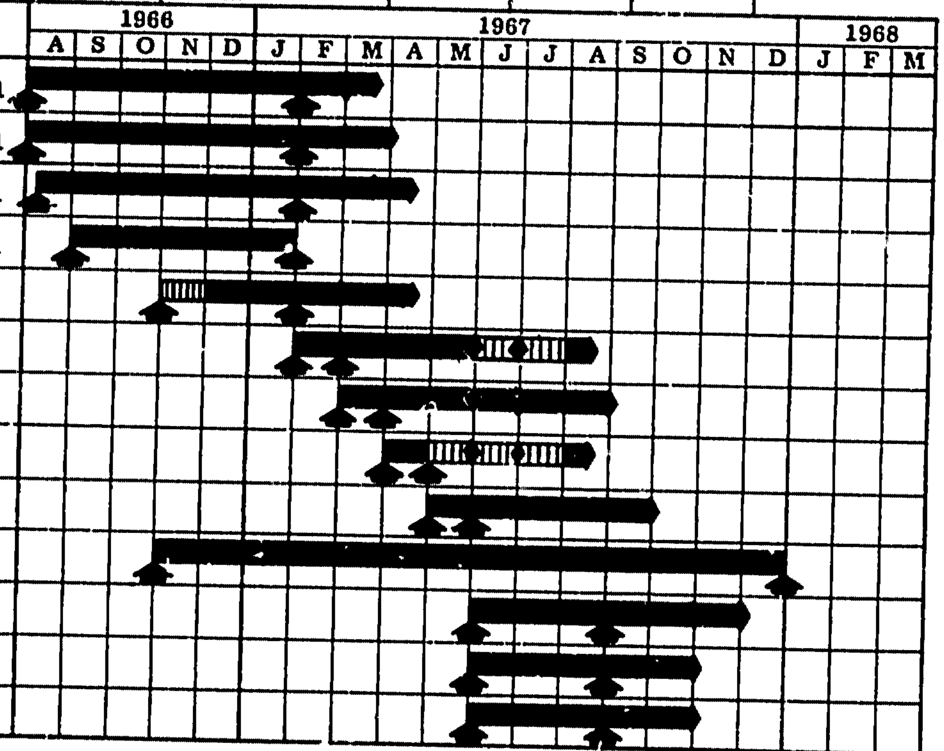
ITEM NO.	MAJOR MILESTONES	NMCSSC CODE
1	Theater War Game Model Development	B-221
2	Division Operations Model Development	B-221
3	Amphibious Warfare Model Development	B-221
4	Counterguerrilla Warfare Model Development	B-221
5	Theater Quick Game Model Development	B-221
6	Test Draft TBM-68	B-221
7	Revise TBM-68	B-221
8	Re-Test TBM-68	B-221
9	Re-Revise TBM-68	B-221
10	Index and Glossary	B-221
11	Write-Up Theater War Game Model	B-221
11a	U. S. Version	B-221
11b	Sanitized Version	B-221



SCHEDULED   COMPLETED   TARGET DATE DELAYED   COMPLETED WORK ACTIVITY   DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7

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TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
11c	COFRAM Section	B-221																				
11d	Appendices for Technical Report	B-221																				
12	Write Up Division Operations Model	B-221																				
12a	U. S. Version	B-221																				
12b	Sanitized Version	B-221																				
12c	COFRAM Section	B-221																				
12d	Appendices for Technical Report	B-221																				
13	Write Up Amphibious Warfare Model	B-221																				
13a	U. S. Version	B-221																				
13b	Sanitized Version	B-221																				
13c	COFRAM Section	B-221																				
13d	Appendices for Technical Report	B-221																				
14	Write Up Counterguerrilla Warfare Model	B-221																				

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14a	U. S. Version	B-221																				
14b	Sanitized Version	B-221																				
14c	COFRAM Section	B-221																				
14d	Appendices for Technical Report	B-221																				
15	Write Up Theater Quick Game Model	B-221																				
15a	U. S. Version	B-221																				
15b	Sanitized Version	B-221																				
15c	COFRAM Section	B-221																				
15d	Appendices for Technical Report	B-221																				
16	Document Theater War Game Model	B-221																				
16a	U. S. Version*	B-221																				
16b	Sanitized Version*	B-221																				
16c	COFRAM Section*	B-221																				

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NMCSSC FORM 1 MAY 66 7 *To include step-by-step explanatory problems. PREPARED BY

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
17	Document Division Operations Model	B-221																				
17a	U. S. Version*	B-221																				
17b	Sanitized Version*	B-221																				
17c	COFRAM Section*	B-221																				
18	Document Amphibious Warfare Model	B-221																				
18a	U. S. Version*	B-221																				
18b	Sanitized Version*	B-221																				
18c	COFRAM Section*	B-221																				
19	Document Counterguerrilla Warfare Model	B-221																				
19a	U. S. Version*	B-221																				
19b	Sanitized Version*	B-221																				
19c	COFRAM Section*	B-221																				
20	Document Theater Quick Game Model	B-221																				

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NMCSSC FORM 7 1 MAY 66 *To include step-by-step explanatory problems. PREPARED BY

TITLE AND DESCRIPTION	PLANS & POLICY OFFICE		
TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A.C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F.T. Trippi, B-221, X53780.	CLASSIFICATION	SCHEDULE NO.	
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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966: A S O N D; 1967: J F M A M J J A S O N D; 1968: J F M
20a	U. S. Version*	B-221	
20b	Sanitized Version*	B-221	
20c	COFRAM Section*	B-221	
21	Synthesize TBM-68	B-221	
22	Organize, consolidate: forms, tables and charts	B-221	
23	Prepare Draft Technical Report and Submit to NMCSSC	B-221	Submitted
24	Final Draft TBM-68 to NMCSSC	B-221	Last Model submitted 2 Apr 68
25	TBM-68 to Printer	B-221	Last Model to printer
26	TBM-68 to NMCSSC	B-221	Last Model Distributed
27	Receive Comments on Technical Report	B-221	Comments Received
28	Submit Final Technical Report to NMCSSC	B-221	Submitted
		B-221	
		B-221	

SCHEDULED — COMPLETED — TARGET DATE DELAYED — COMPLETED WORK ACTIVITY — DELAYED WORK ACTIVITY

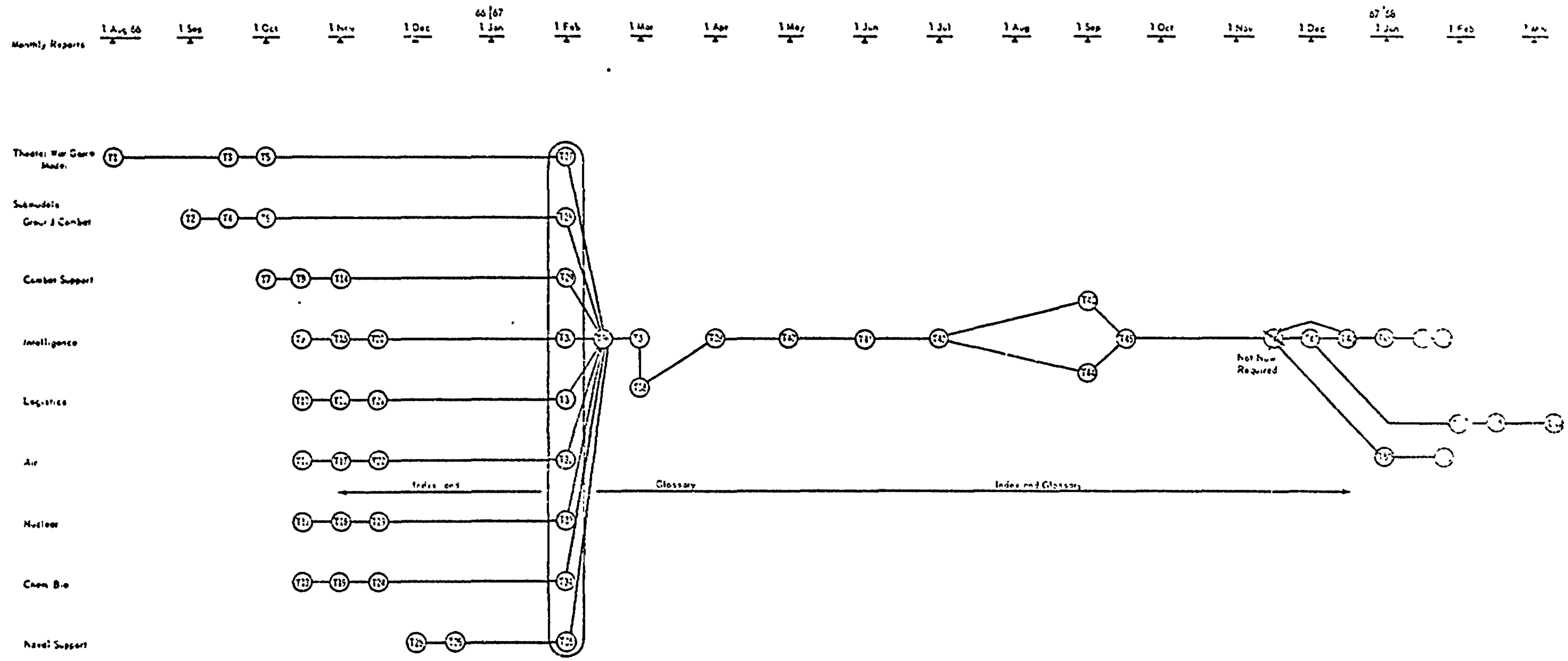
NMCSSC FORM 7, 1 MAY 66

*To include step-by-step explanatory problems.

PREPARED BY ____________

Section 5

5.1 Theater War Game Model
PERT TYPE CHART



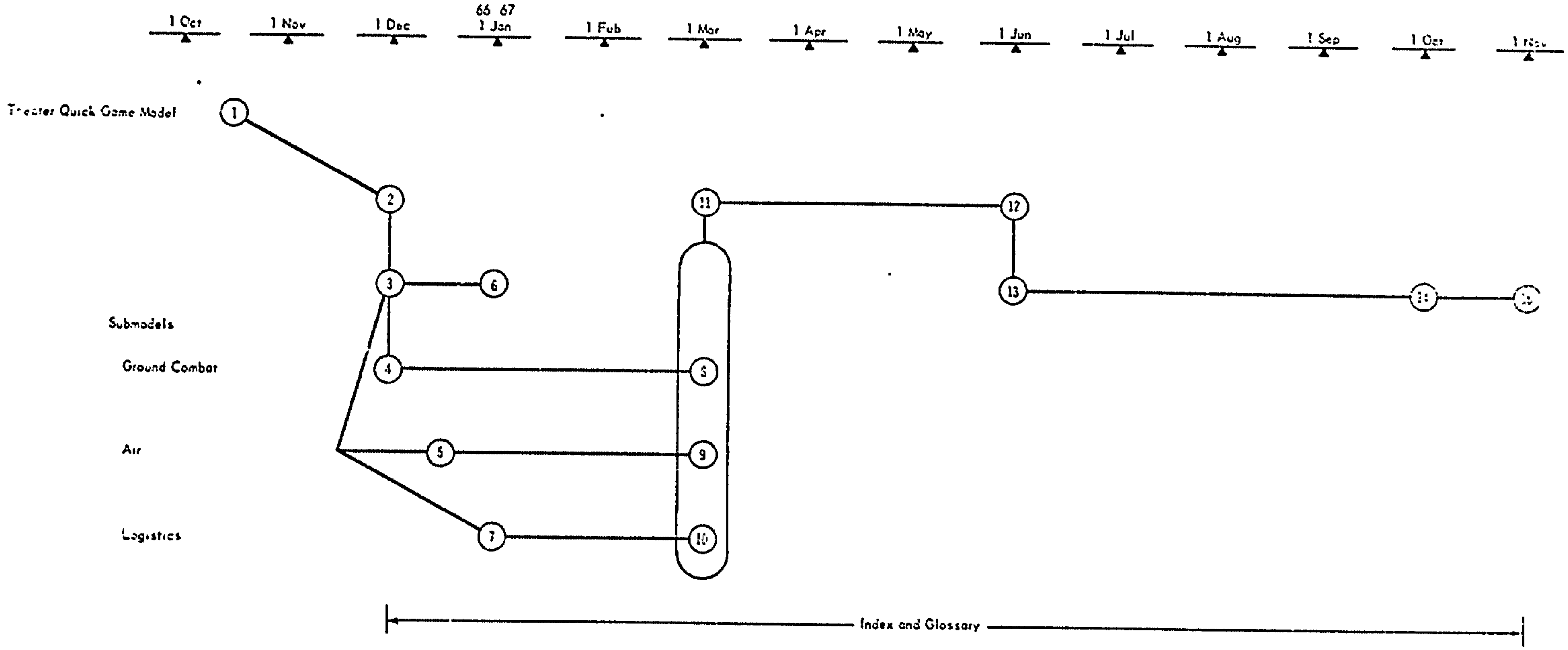
Major Events

▲ Reports due First Day of Month

Completed task

T1 Begin Theater War Game Model—Submit PERT Chart (23 Aug)
T2 Begin Ground Combat Submodel
T3 Submit concept for Theater War Game Model
T4 Submit PERT Chart Ground Combat Model
T5 Receive comments on Theater War Game Model
T6 Submit concept on Ground Combat Model
T7 Begin Combat Support Submodel
T8 Submit PERT Chart on Combat Support Submodel
T9 Begin Intelligence Submodel
T10 Begin Logistics Submodel
T11 Begin Air Submodel
T12 Begin Nuclear Submodel
T13 Begin Chem Bio Submodel
T14 Submit concept for Combat Support Submodel
T15 Submit PERT Chart Intelligence Submodel
T16 Submit PERT Chart Logistics Submodel
T17 Submit PERT Chart Air Submodel
T18 Submit PERT Chart Nuclear Submodel
T19 Submit PERT Chart Chem Bio Submodel
T20 Submit concept for Intelligence Submodel
T21 Submit concept for Logistics Submodel
T22 Submit concept for Air Submodel
T23 Submit concept for Nuclear Submodel
T24 Submit concept for Chemical Biological Submodel
T25 Begin Naval Support Submodel
T26 Submit PERT Chart and concept for Naval Support Submodel
T27–
T35 Complete Development of Model and Submodels
T36 Test model for compatibility with Direct on Operations, Amphibious Warfare and Counterguerrilla Models [illegible] Feb
T37 Conduct Test War Game 16 Feb to 1 Mar
T38 Begin revision based on test
T39 Revision made
T40 [illegible]
T41 Begin writeup of Theater War Game Model
T42 Begin appendices for Technical Report
T43 Complete write up of technical aspects of model and appendices for Technical Report
T44 Begin final draft preparation
T45 Obtain approval of [illegible]
T46 Final test of model [illegible]
T47 Begin [illegible] Technical Report
T48 Prepare Abstract [illegible]
T49 Submit [illegible] documentation [illegible] and [illegible]
T50 Prepare [illegible]
T51 Receive NMCSSC comments [illegible]
T52 Submit [illegible] Technical Report
T53 Complete [illegible] to printer
T54 Complete and submit draft of Technical Report
T55 Receive NMCSSC comments
T56 Correct Technical Report and print

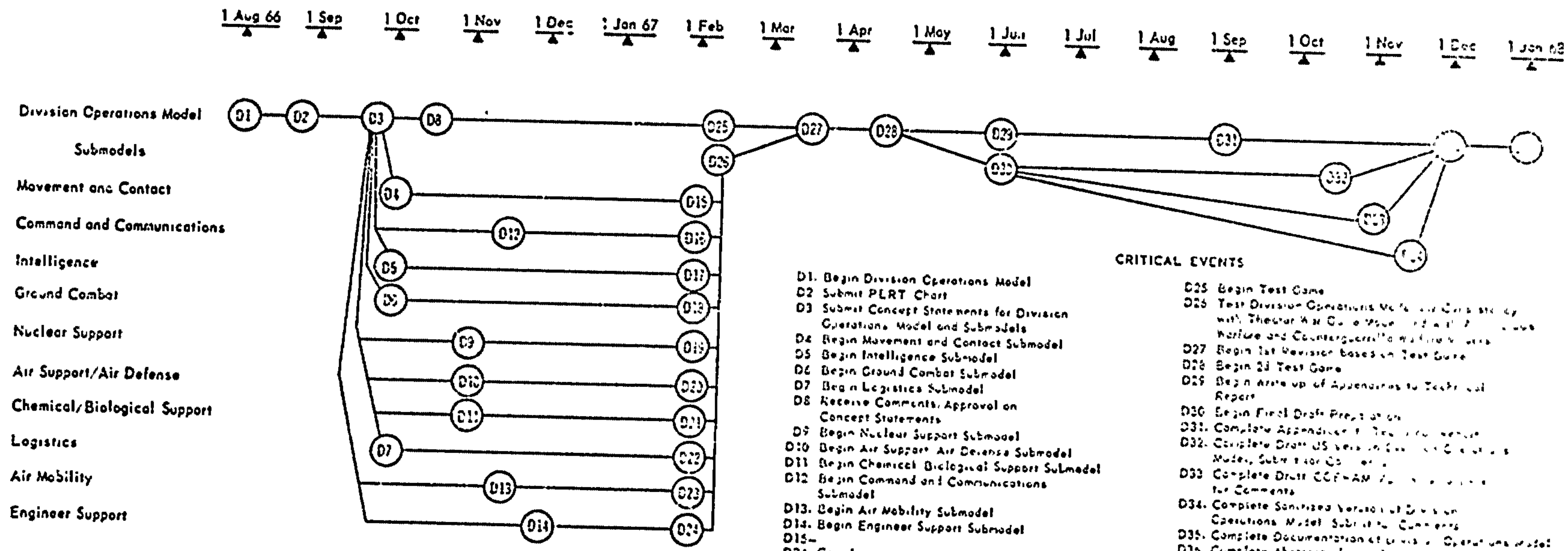
5.2 Theater Quick Game Model
PERT TYPE CHART



CRITICAL EVENTS

1 Submit PERT type chart for Theater Quick Game Model
2 Submit Concept statement for Theater Quick Game Model and submodels
3 Begin TQG Model development
4 Begin Ground Combat Submodel
5 Begin Air Submodel
6 Receive Comments concerning Concept Statement
7 Begin Logistics Submodel
8 Complete Ground Combat Submodel
9 Complete Air Submodel
10 Complete Logistics Submodel
11 Begin Tests and Revisions of TQG Model for compatibility with other [illegible]
12 Complete Tests and Revisions of TQG Model
13 Begin write-up of TQG Model including US and sanitized versions and COFRAM [illegible]
14 Complete write-up of TQG Model
15 Complete all documentation of TQG Model including appendices for the Technical Report

5.3 Division Operations Model
PERT TYPE CHART



D1. Begin Division Operations Model
D2 Submit PERT Chart
D3 Submit Concept Statements for Division Operations Model and Submodels
D4 Begin Movement and Contact Submodel
D5 Begin Intelligence Submodel
D6 Begin Ground Combat Submodel
D7 Begin Logistics Submodel
D8 Receive Comments, Approval on Concept Statements
D9 Begin Nuclear Support Submodel
D10 Begin Air Support Air Defense Submodel
D11 Begin Chemical Biological Support Submodel
D12 Begin Command and Communications Submodel
D13. Begin Air Mobility Submodel
D14. Begin Engineer Support Submodel
D15–
D24. Complete appropriate Submodels

CRITICAL EVENTS

D25 Begin Test Game
D26 Test Division Operations Model [illegible] with Theater War Game [illegible] Warfare and Counterguerrilla [illegible]
D27 Begin 1st Revision based on Test Game
D28 Begin 2d Test Game
D29 Begin write up of Appendixes to Technical Report
D30 Begin Final Draft Preparation
D31. Complete Appendixes [illegible]
D32. Complete Draft US version [illegible] Model, Submit for Comments
D33 Complete Draft CCF-AM [illegible] for Comments
D34. Complete Sanitized Version of Division Operations Model Submit for Comments
D35. Complete Documentation of Division Operations Model
D36. Complete Abstracts for each [illegible]

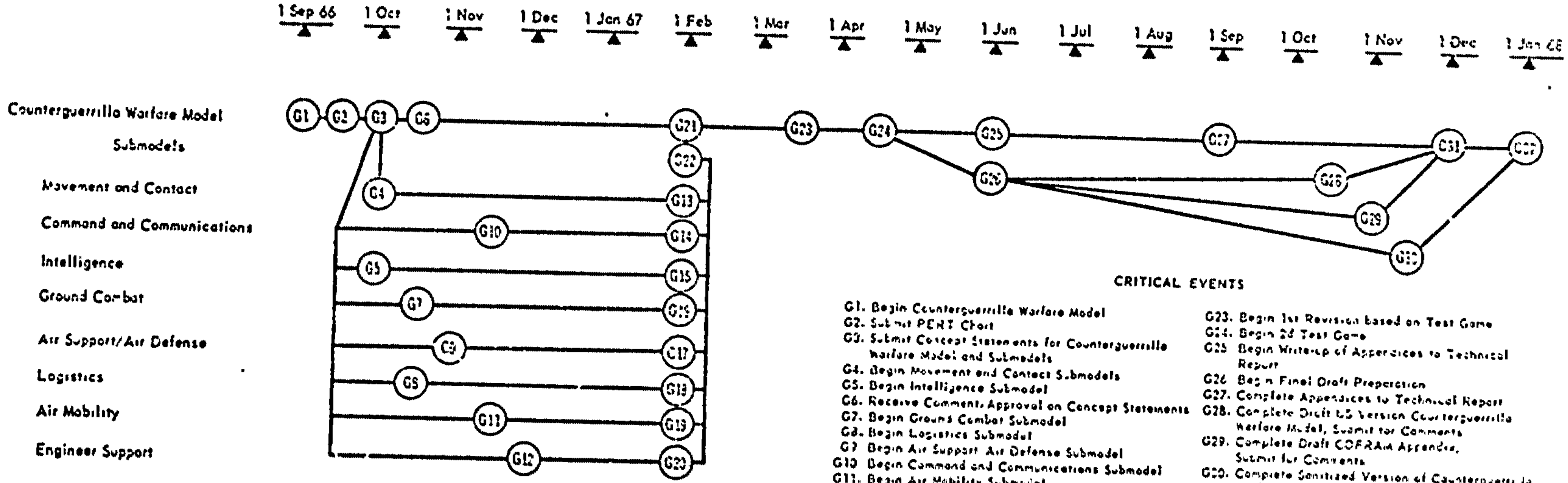
▲ First day of month. Monthly reports due.

◯ Completed task

D26

5.4 Counterguerrilla Warfare Model

PERT TYPE CHART



▲ First day of month   Monthly reports due.

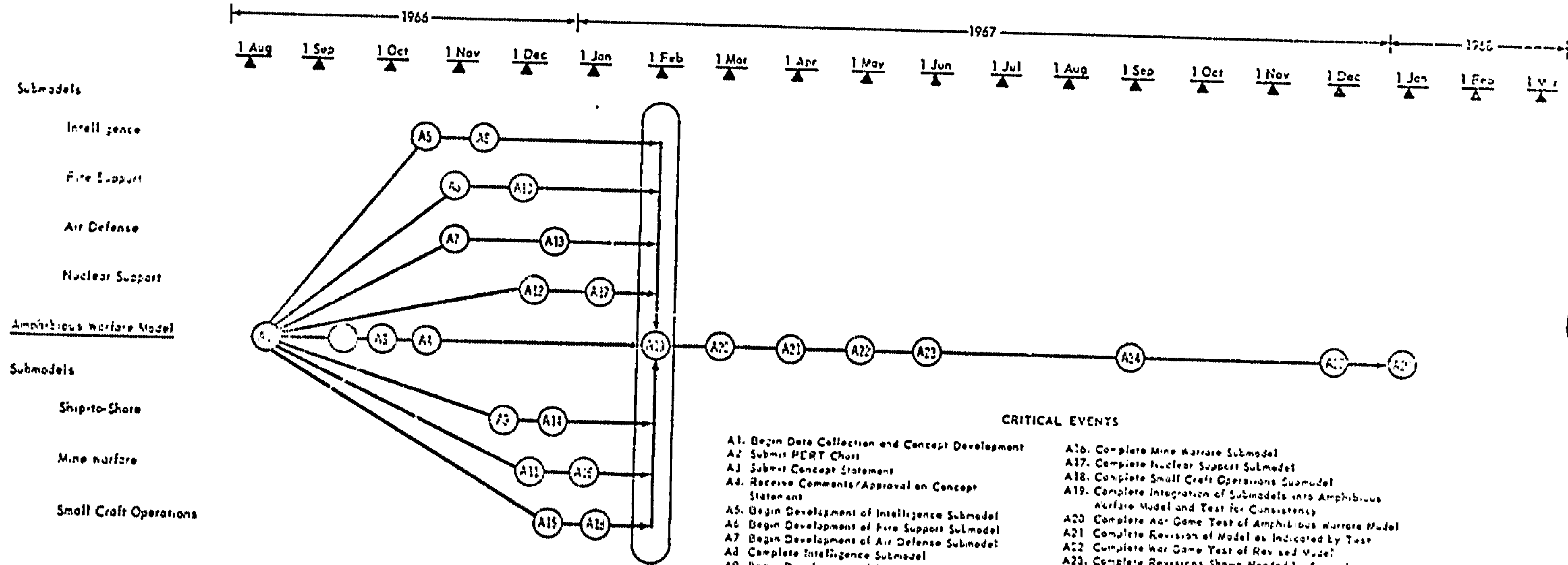
◯ Completed task

CRITICAL EVENTS

G1. Begin Counterguerrilla Warfare Model
G2. Submit PERT Chart
G3. Submit Concept Statements for Counterguerrilla Warfare Model and Submodels
G4. Begin Movement and Contact Submodels
G5. Begin Intelligence Submodel
G6. Receive Comment, Approval on Concept Statements
G7. Begin Ground Combat Submodel
G8. Begin Logistics Submodel
G9. Begin Air Support Air Defense Submodel
G10. Begin Command and Communications Submodel
G11. Begin Air Mobility Submodel
G12. Begin Engineer Support Submodel
G13–
G20. Complete appropriate Submodels
G21. Begin Test Game
G22. Test Counterguerrilla Warfare Model for Consistency with Division Operations Model
G23. Begin 1st Revision based on Test Game
G24. Begin 2d Test Game
G25. Begin Write-up of Appendices to Technical Report
G26. Begin Final Draft Preparation
G27. Complete Appendices to Technical Report
G28. Complete Draft US Version Counterguerrilla Warfare Model, Submit for Comments
G29. Complete Draft COFRAM Appendix, Submit for Comments
G30. Complete Sanitized Version of Counterguerrilla Warfare Model, Submit for Comments
G31. Complete Documentation of Counterguerrilla Warfare Model
G32. Complete Abstracts for each Volume

5.5 Amphibious Warfare Model

PERT TYPE CHART



▲ First day of month. Monthly reports due.

◯ Completed task

CRITICAL EVENTS

A1. Begin Data Collection and Concept Development
A2. Submit PERT Chart
A3. Submit Concept Statement
A4. Receive Comments/Approval on Concept Statement
A5. Begin Development of Intelligence Submodel
A6. Begin Development of Fire Support Submodel
A7. Begin Development of Air Defense Submodel
A8. Complete Intelligence Submodel
A9. Begin Development of Ship-to-Shore Submodel
A10. Complete Fire Support Submodel
A11. Begin Development of Mine Warfare Submodel
A12. Begin Development of Nuclear Support Submodel
A13. Complete Air Defense Submodel
A14. Complete Ship-to-Shore Submodel
A15. Begin Development of Small Craft Operations Submodel
A16. Complete Mine Warfare Submodel
A17. Complete Nuclear Support Submodel
A18. Complete Small Craft Operations Submodel
A19. Complete Integration of Submodels into Amphibious Warfare Model and Test for Consistency
A20. Complete War Game Test of Amphibious Warfare Model
A21. Complete Revision of Model as Indicated by Test
A22. Complete War Game Test of Revised Model
A23. Complete Revisions Shown Needed by Second War Game Test
A24. Complete Writeup of Amphibious Warfare Model and Appendices for Technical Report
A25. Complete Documentation of Amphibious Warfare Model (US Version, COFRAM Appendix, and Sanitized Version)
A26. Complete Abstracts for each Volume.

Section 6

MODIFIED MILESTONE CHARTS FOR EACH MODEL

6.1 THEATER WAR GAME MODEL

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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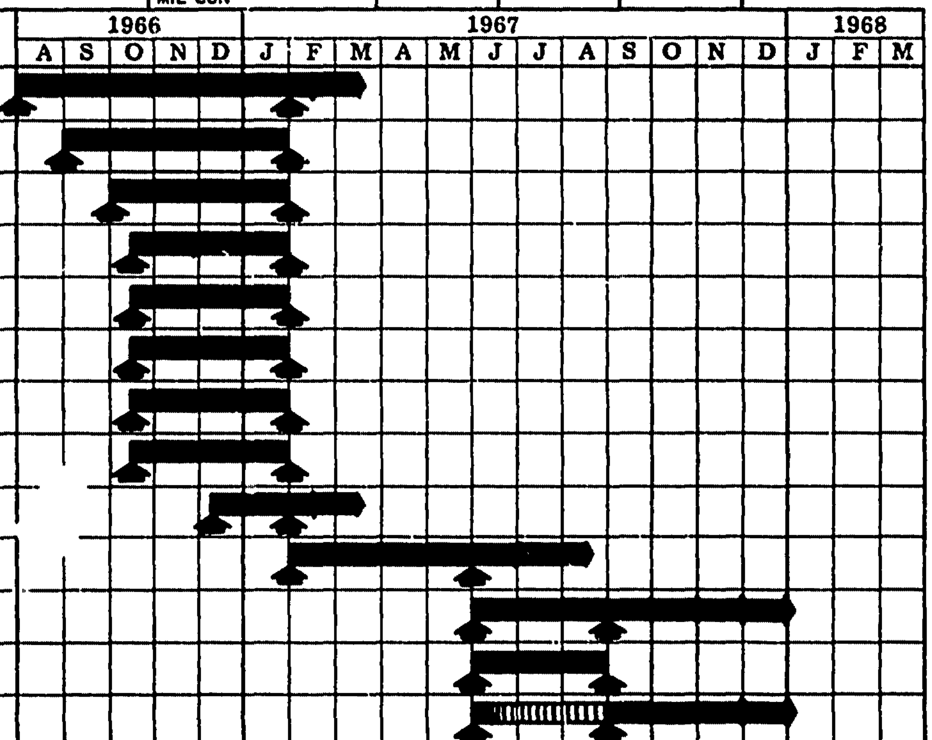
ITEM NO.	MAJOR MILESTONES	NMCSSC CODE
T1	Theater War Game Model Development	B-221
	Ground Combat Submodel Development	B-221
	mbat Support Submodel Development	B-221
	Intelligence Submodel Development	B-221
T5	Logistics Submodel Development	B-221
T6	Air Submodel Development	B-221
T7	Nuclear Submodel Development	B-221
T8	Chem/Bio Submodel Development	B-221
T9	Naval Support Submodel Development	B-221
T10	Test and Revise Theater War Game Model	B-221
T11	Write-Up Theater War Game Model	B-221
T11a	US Version	B-221
T11b	COFRAM Appendix	B-221



SCHEDULED COMPLETED TARGET DATE DELAYED

COMPLETED WORK ACTIVITY

DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7

PREPARED BY

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 (A S O N D) – 1967 (J F M A M J J A S O N D) – 1968 (J F M)
T11c	Sanitized Version	B-221	
T12	Obtain Approval of Format if Automated	B-221	
T13	Final Draft of Model	B-221	
T14	Final Test of Model	B-221	Not now required
T15	Final Corrected Draft	B-221	
T15a	US Version	B-221	
T15b	COFRAM Appendix	B-221	
T15c	Sanitized Version	B-221	
T16	Turn Over Reproducible Mats	B-221	
T17	Draft Technical Report	B-221	Technical Report Submitted
T18	Prepare Blank Forms	B-221	
T19	Revise and Print Technical Report	B-221	Technical Report To Printer
T20	Index and Glossary	B-221	

SCHEDULED — COMPLETED — TARGET DATE DELAYED — COMPLETED WORK ACTIVITY — DELAYED WORK ACTIVITY

NMCSSC FORM 7, 1 MAY 66

PREPARED BY ____________

6.2 THEATER QUICK GAME MODEL

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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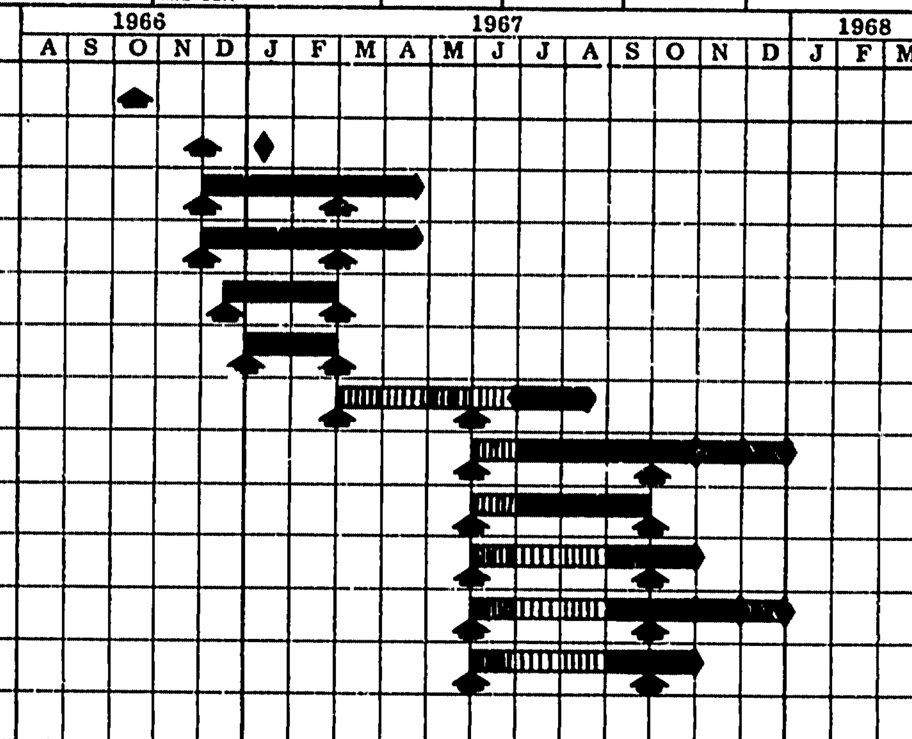
ITEM NO.	MAJOR MILESTONES	NMCSSC CODE
Q1	Theater Quick Game Model PERT type Chart	B-221
Q2	Concept Statement for Theater Quick Game	B-221
Q3	Theater Quick Game Model Development	B-221
Q3a	Ground Combat Submodel Development	B-221
Q3b	Air Submodel Development	B-221
Q3c	Logistics Submodel Development	B-221
Q4	Tests and Revisions of Theater Quick Game Model	B-221
Q5	Write-Up of Theater Quick Game Model	B-221
Q5a	US Version	B-221
Q5b	Sanitized Version	B-221
Q5c	COFRAM Appendix	B-221
Q5d	Appendix(es) for Technical Report	B-221
	(continued on next page)	



SCHEDULED · COMPLETED · TARGET DATE DELAYED · COMPLETED WORK ACTIVITY · DELAYED WORK ACTIVITY

NMCSSC FORM 7, 1 MAY 66

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TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
Q6	Document Theater Quick Game Model	B-221																				
Q6a	U.S. Version	B-221																				
Q6b	Sanitized Version	B-221																				
Q6c	COFRAM Appendix	B-221																				
		B-221																				
		B-221																				
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SCHEDULED   COMPLETED   TARGET DATE DELAYED   COMPLETED WORK ACTIVITY   DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7   PREPARED BY

6.3 DIVISION OPERATIONS MODEL

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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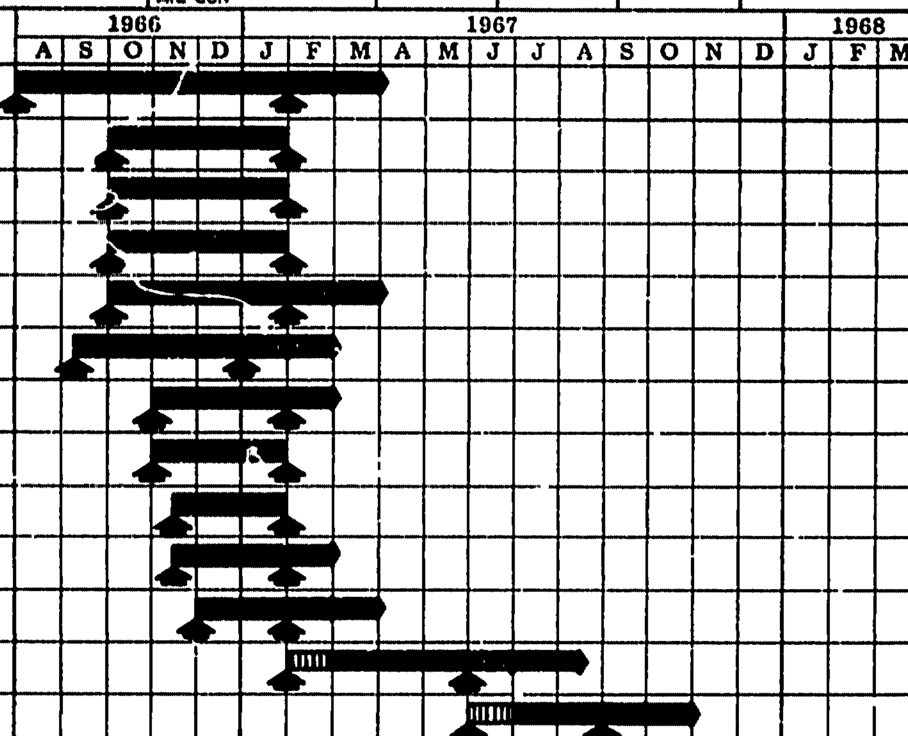
ITEM NO.	MAJOR MILESTONES	NMCSSC CODE
D-1	Division Operations Model Development	B-221
D-2	Movement and Contact Submodel	B-221
D-3	Intelligence Submodel	B-221
D-4	Ground Combat Submodel	B-221
D-5	Logistics Submodel	B-221
D-6	Nuclear Submodel	B-221
D-7	Air Support/Air Defense Submodel	B-221
D-8	Chemical/Biological Support Submodel	B-221
D-9	Command and Communications Submodel	B-221
D-10	Air Mobility Submodel	B-221
D-11	Engineer Support Submodel	B-221
D-12	Test and Revise Division Operations Model	B-221
D-13	Appendices to Technical Report	B-221



SCHEDULED · COMPLETED · TARGET DATE DELAYED · COMPLETED WORK ACTIVITY · DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7 PREPARED BY ______

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
D-14	Write Up Division Operations Model	B-221																				
D-14a	U. S. Version	B-221																				
D-14b	Sanitized Version	B-221																				
D-14c	COFRAM Appendix	B-221																				
D-15	Document of Div. Opns. Model	B-221																				
D-15a	U. S. Version	B-221																				
D-15b	Sanitized Version	B-221																				
D-15c	COFRAM Appendix	B-221																				
		B-221																				
		B-221																				
		B-221																				
		B-221																				
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SCHEDULED   COMPLETED   TARGET DATE DELAYED   COMPLETED WORK ACTIVITY   DELAYED WORK ACTIVITY

NMCSSC FORM 7 1 MAY 66   PREPARED BY

6.4 COUNTERGUERRILLA WARFARE MODEL

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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CLASSIFICATION	SCHEDULE NO.		
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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
G1	Counterguerrilla Warfare Model Development	B-221																				
G2	Submit Concept Statement	B-221																				
G3	Movement and Contact Submodel	B-221																				
G4	Intelligence Submodel	B-221																				
G5	Ground Combat Submodel	B-221																				
G6	Receive Comments on Concept Statement	B-221																				
G7	Logistics Submodel	B-221																				
G8	Air Support/Air Defense Submodel	B-221																				
G9	Command and Communications Submodel	B-221																				
G10	Air Mobility Submodel	B-221																				
G11	Engineer Support Submodel	B-221																				
G12	Test and Revise Counterguerrilla Warfare Model	B-221																				
G13	Appendices to Technical Report	B-221																				

SCHEDULED COMPLETED TARGET DATE DELAYED COMPLETED WORK ACTIVITY DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7

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TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966					1967												1968		
			A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
G14	Write-up Counterguerrilla Warfare Model	B-221																				
G14a	US Version	B-221																				
G14b	COFRAM Appendix	B-221																				
G14c	Sanitized Version	B-221																				
G15	Documentation of Counterguerrilla Warfare Model	B-221																				
G15a	US Version	B-221																				
G15b	COFRAM Appendix	B-221																				
G15c	Sanitized Version	B-221																				
		B-221																				
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SCHEDULED — COMPLETED — TARGET DATE DELAYED — COMPLETED WORK ACTIVITY — DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7 PREPARED BY

6.5 AMPHIBIOUS WARFARE MODEL

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWGA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966 A	S	O	N	D	1967 J	F	M	A	M	J	J	A	S	O	N	D	1968 J	F	M
A1	Amphibious Warfare Model Development	B-221																				
A2	Intelligence Submodel	B-221																				
A3	Fire Support Submodel	B-221																				
A4	Air Defense Submodel	B-221																				
A5	Ship-To-Shore Submodel	B-221																				
A6	Mine Warfare Submodel	B-221																				
A7	Nuclear Support Submodel	B-221																				
A8	Small Craft Operations Submodel	B-221																				
A9	Test and Revise Amphibious Warfare Model	B-221																				
A10	Write-Up Amphibious Warfare Model	B-221																				
A10a	US Version	B-221																				
A10b	COFRAM Appendix	B-221																				
A10c	Sanitized Version	B-221																				

◇ SCHEDULED ◆ COMPLETED ◆ TARGET DATE DELAYED COMPLETED WORK ACTIVITY DELAYED WORK ACTIVITY

NMCSSC FORM 1 MAY 66 7 * Actually started 17 October 1966 PREPARED BY

TITLE AND DESCRIPTION—Revision of the Theater Battle Model (TBM-63): To redesign, refine, and update the TBM-63 with emphasis on quality improvements to make the model more flexible and universally acceptable to meet the varying war gaming requirements of the JWCA, the Unified and Specified Commands, and the Services. JWGA Memo 421-65, 4 Nov 65; JWGA Memo 031-66, 26 Jan 66; and MIPR 43-6-43, 22 Jul 66. Project Manager: LTC A. C. Costanzo, USA, B-221, X53780. Project Officer: Mr. F. T. Trippi, B-221, X53780.

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ITEM NO.	MAJOR MILESTONES	NMCSSC CODE	1966					1967												1968		
			A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
A11	Appendices to Technical Report	B-221																				
A12	Documentation of Amphibious Warfare Model	B-221		Submitted for Review 2 Apr 68																		
A12a	US Version	B-221					"															
A12b	COFRAM Appendix	B-221					"															
A12c	Sanitized Version	B-221					"															
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SCHEDULED COMPLETED TARGET DATE DELAYED

COMPLETED WORK ACTIVITY
DELAYED WORK ACTIVITY

NMCSSC FORM 7 1 MAY 66

PREPARED BY

Section 7

PUBLICATION SCHEDULE

Model	Document Title	Document number	Principal author	No. of pages: Estimated	No. of pages: Actual	Security classification	Draft to NMCSSC: Planned	Draft to NMCSSC: Actual	Draft Returned: Planned	Draft Returned: Actual	Publication Date: Planned	Publication Date: Actual	Remarks
TWGM	Vol I TBM-68, Theater War Game Model	RAC-R-36	Elmore	650			2 Jan 68	8 Mar 68	15 Jan 68	25 Apr 68	22 Jan 68	21 Apr 69	
	Part I, Chaps 1, 2, 3 Part II, Chaps 4, 5, 6, 7 Part III, Appendixes				343 219 319	S S-FRD S							
	Vol IF - (Foreign Version)	RAC-R-36	Elmore	600			2 Jan 68	8 Mar 68	15 Jan 68	25 Apr 68	22 Jan 68	25 Apr 69	
	Part I, Chaps 1, 2, 3 Part II, Chaps 4, 5, 6, 7 Part 3, Appendixes				343 219 210	U U U							
TQGM	Vol II TBM-68, Theater Quick Game Model	RAC-R-36	Olson	50	214	S	1 Oct 67	25 Oct 67	15 Oct 67	7 Dec 67	5 Nov 67	15 May 68	
	Vol IIF - (Foreign Version)	RAC-R-36	Olson	30	117	U	1 Oct 67	25 Oct 67	15 Oct 67	7 Dec 67	5 Nov 67	15 May 68	
DOM	Vol III TBM-68, Division Operations Model	RAC-R-36	Whipple	200	504	S-RD	15 Nov 67	8 Jan 68	1 Dec 67	23 Feb 68	20 Dec 67	30 Sep 68	
	Vol IIIF - (Foreign Version)	RAC-R-36	Whipple	180	370	U	15 Nov 67	8 Jan 68	1 Dec 67	23 Feb 68	20 Dec 67	30 Sep 68	
CGWM	Vol IV TBM-68, Counter-guerrilla Warfare Model	RAC-R-36	Parker	135	341	S	15 Oct 67	21 Oct 67	1 Nov 67	22 Nov 67	20 Nov 67	20 Apr 68	
	Vol IVF - (Foreign Version)	RAC-R-36	Parker	125	191	U	15 Oct 67	21 Oct 67	1 Nov 67	22 Nov 67	20 Nov 67	20 Apr 68	
AWM	Vol V TBM-68, Amphibious Warfare Model	RAC-R-36	Raring	80			15 Dec 67	2 Apr 68	2 Jan 68	10 Jul 68	15 Jan 68	8 Jan 69	
	Part I, Part II, Appendixes				343 212	S-RD S							
	Vol VF - (Foreign Version)	RAC-R-36	Raring	70	415	U	15 Dec 67	2 Apr 68	2 Jan 68	10 Jul 68	15 Jan 68	8 Jan 69	
COFRAM Supplement	Vol VI TBM-68, COFRAM Supplement	RAC-R-36	Olson	40	62	S-SH	1 Oct 67	11 Jan 68	5 Nov 67	29 Feb 68	2 Jan 68	10 Jul 68	
Technical Report	Vol VII TBM-68, Technical Report	RAC-R-36	Zimmerman	30	177	U	31 Jan 68	10 Mar 69	15 Feb 68	20 Mar 69	1 Mar 68	15 Apr 69	

Section 8

TASK/PERSONNEL SUMMARY

8.1 AUTHORS AND CONTRIBUTING PERSONNEL

8.1.1 Theater War Game Model

The principal author of the TWGM was John A. Elmore, BG USA (Ret).

Authors and contributing personnel to specific chapters of this model were:

Chap. 1 — General — John A. Elmore BG, USA (Ret)
Chap. 2 — Ground Combat and Combat Support Submodel — H. J. Vander Heide, MG, USA (Ret)
Chap. 3 — Air Submodel — N. C. Bonawitz, Col, USAF (Ret); contributing — A. F. Binney, MG, USMC (Ret), W. R. Schilling, F. D. Genova, S. A. Marciniec; consultants — Gilbert L. Meyers, MG, USAF (Ret), Chas E. Myers, Jr.
Chap. 4 — Intelligence Submodel — J. D. Stevens, BG, USA (Ret); contributing — F. D. Genova, R. Voigt.
Chap. 5 — Logistic Submodel — J. T. Goodley, Col, USA (Ret); contributing — J. T. Small, D. Parker, Col, USA (Ret).
Chap. 6 — Nuclear Submodel — P. C. Wehle, MG, USA (Ret); contributing — R. G. Hendrickson.
Chap. 7 — Chemical-Biological Submodel — L. R. Seibert, Col, USMC (Ret); consultant, Marshall Stubbs, MG, USA (Ret).

8.1.2 Theater Quick Game Model

The principal author of the TQGM was Howard C. Olson. A contributing author was D. W. Mader.

8.1.3 Division Operations Model

The principal author of the DOM was Sherburne Whipple, BG, USA (Ret). Contributing authors were C. O. Smeak, Jr., H. N. Hantzes, Jr, and N. W. Parsons, LTC, USA (Ret).

The authors of the Nuclear Submodel were P. C. Wehle, MG, USA (Ret) and R. G. Hendrickson.

The authors of the Chemical-Biological Submodel were L. R. Seibert, COL, USMC (Ret) and Marshall Stubbs, MG, USA (Ret).

8.1.4 Counterguerrilla Warfare Model

The principal author of the CGWM was Daniel Parker, Col, USA (Ret). A contributing author was R. F. Patchett.

8.1.5 Amphibious Warfare Model

The principal author of the AWM was G. L. Raring, Capt, USN (Ret). A contributing author was W. N. Flournoy, Col, USMC (Ret).

8.1.6 Firepower Scores

The firepower scores tasks included App A, "Indexes of Fire Power Potential," published with each of the gaming manuals and the "COFRAM Supplement." Mr. Howard C. Olson was the author of these portions of the project. Also included under this task was the infantry-tank unit trade-off study, reported on in this volume for which C. A. Bruce, Jr. was the author.

8.2 MANPOWER UTILIZATION

The manpower requirements for the TBM-68 project were originally estimated to be 22 Technical Man Years (TMY) of effort. This was calculated to provide 45,746 man-hours of work on the basis of 173.33 man-hours per Technical Man Month (TMM). During the course of the project it was determined that the actual man-hour to man-month relationship should have been on the basis of 147.3 man-hours per man-month for permanent technical personnel and 173.3 man-hours for part-time and consultant personnel.

The total manpower actually used in accomplishing the TBM-68 project was 44,554.3 man-hours or 275.36 TMM as compared to 45,746 man-hours and 264 TMM originally estimated.

The break-down of manpower utilization by task was as follows:

Task	Technical Man-hours Planned	Technical Man-hours Actual	Percent of Effort Planned	Percent of Effort Actual
Theater War Game Model	11,956	16,520.5	26.1	36.2
Theater Quick Game Model	1,906	1,011.0	4.2	2.2
Division Operations Model	11,263	9,376.5	24.6	20.5
Counterguerrilla Warfare Model	3,466	3,696.5	7.6	8.1
Amphibious Warfare Model	3,466	5,105.0	7.6	11.2
Firepower Scores	2,772	2,674.0	6.0	5.9
Management and Documentation	10,917	7,270.8	23.9	15.9
Totals man-hours	45,746	45,654.3	100.0	100.0
TMM	264	275.36		

Section 9

FUNDS EXPENDITURE

Month ending	Voucher number	Direct Labor	Operating overhead	Expendable Materials: Computer time	Expendable Materials: Materials	Travel	G & A expense	Fee	Adjustments	Obligations	Monthly Total
Contract Estimates		$412,760	$280,680	$48,000 $30,500	$17,500	$8,000	$48,710	$39,050	--	--	$837,200
31 Aug 66		7,719	4,849	--	--	6	733	--	--	--	13,307
30 Sep 66		17,168	11,446	567	62	24	2,179	(cum) 2,240	--	--	33,686
31 Oct 66		44,977[a]	15,953	--	--	185	4,139	3,925	--	--	69,179
30 Nov 66		31,463	24,894	(58)	195	15	4,989	2,055	--	--	63,553
31 Dec 66		27,055	19,584	--	14	12	2,988	2,055	--	--	51,708
31 Jan 67		31,459	24,565	15	67	6	4,507	2,055	--	--	62,674
28 Feb 67		41,821	33,172	90	91	--	5,559	2,055	--	--	82,788
31 Mar 67		37,292	25,571	445	232	3	5,966	2,055	--	--	71,564
30 Apr 67		31,490	20,486	137	86	--	3,339	2,055	--	--	57,593
31 May 67		31,857	22,352	7,012	587	110	4,317	2,055	--	--	68,290

a. Includes subcontract of $19,677.00

Month ending	Voucher number	Direct labor	Operating overhead	Expendable materials: Computer time	Expendable materials: Materials	Travel	G & A expense	Fee	Adjustments	Obligations	Monthly total
				$48,000							
Contract estimates		$412,760	$280,680	$30,500	$17,500	$8,000	$48,710	$39,050	--	--	$837,200
30 Jun 67		34,161	20,922	6,045	1,497	47	4,730	2,055	--	--	69,457
31 Jul 67		25,883	12,808	4,327	320	26	3,139	2,055	--	--	48,558
31 Aug 67		28,940	8,843	(31)	343	28	3,009	2,055	--	--	43,187
30 Sep 67		16,598	6,912	(1,480)	(373)	22	2,732	2,055	--	--	25,466
31 Oct 67		23,715	12,387	- 0 -	60	29	3,921	2,055	--	--	42,167
30 Nov 67		8,141	4,195	- 0 -	- 0 -	12	1,042	2,055	--	--	15,445
31 Dec 67		15,157	8,400	- 0 -	139	30	2,128	2,055	--	--	27,909
31 Jan 68		3,631	2,154	- 0 -	6	- 0 -	502	2,055	--	--	8,348
29 Feb 68		2,801	1,714	- 0 -	- 0 -	- 0 -	452	2,055	--	--	7,022
31 Mar 68		3,148	1,562	- 0 -	120	- 0 -	456	- 0 -	--	--	5,286
30 Apr 68		1,067	532	- 0 -	- 0 -	- 0 -	178	5	--	--	1,782
31 May 68		508	286	- 0 -	30	- 0 -	81	- 0 -	--	--	905
TOTALS (from 1 Aug 66)		$466,051	$283,587	$12,742	$ 7,801	$ 555	$60,086	$39,050	--	--	$869,872

Note: The question of funding the cost overrun to complete the project is unresolved as of the date of publication of this report.